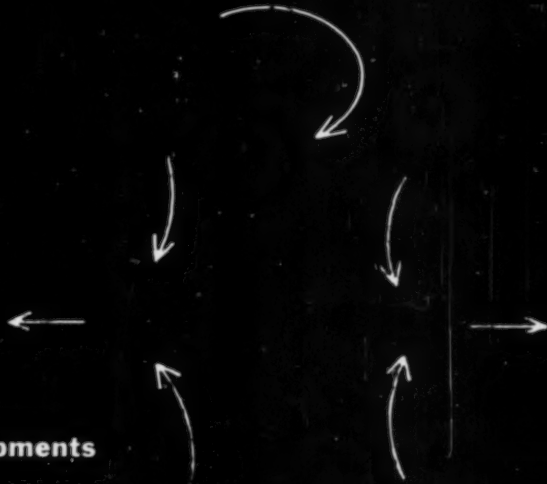


Chemical Engineering Progress

DECEMBER 1954

MIXING

C. E. P. brings you up-to-date on developments



Louisville Method

Louisville Dryer "Family" boosts production, cuts costs for chemical manufacturer

Dryer Types Installed
in one Plant Since 1933



10 ft. x 100 ft. size
largest ever built!

Pilot Dryer
38 in. x 25 ft. size

Some years ago a large chemical company bought the smallest commercial Louisville Steam Tube Dryer as a pilot plant for a new product. Today this firm owns a whole "family" of Louisville Dryers, ranging from their original small pilot plant to the largest steam tube dryers ever built, Louisville's 10 ft. x 100 ft. rotary dryers.

Large or small, there's a *right* size dryer for your job. Louisville relieves you of guesswork about dryer size, type or construction. Our engineers survey your problem . . . their recommendations are job-tested in our pilot plant. Your Louisville Dryer is *built*—not assembled—and built right for your job. Its performance is backed by over 50 years of successful drying experience.

Ask one of our drying specialists to look over your problems. No obligation, of course.



**LOUISVILLE DRYING
MACHINERY UNIT**
*over 50 years of creative
drying engineering*

GENERAL AMERICAN TRANSPORTATION CORPORATION

Dryer Sales Offices: 139 South Fourth Street, Louisville 2, Kentucky
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OFFICES IN ALL PRINCIPAL CITIES

Other General American Equipment: Turbo-Mixers • Dewaterers
Towers • Tanks • Pressure Vessels

For dependability see General American—creative engineering, design, construction, installation

Chemical Engineering Progress

DECEMBER, 1954

VOLUME 50, NO. 12

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H. R. Glennon

Editorial Assistants
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opinion and comment

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The ViBrox Barrel and Drum Packer with the exclusive mechanical rocking-vibrating motion packs more material in the drum or barrel or permits the use of smaller, lower-cost containers; cuts packing time; and reduces packing labor as much as one-third. Yes, in packing most dry powdered, flake, or granular materials, the ViBrox Packer makes a big difference in the over-all packing costs—big enough, many users say, to pay for the ViBrox in a few months.

Operation of the ViBrox is continuous. No clamping of the container is necessary as the motion of the platform keeps the container in place. And, the rugged construction of the ViBrox Packer has proved capable of trouble-free daily service for years, even when packing the heaviest containers.

Several sizes of ViBrox Packers are available for packing boxes, cans, cartons, kegs, drums, and barrels having capacities of from 5 to 1000 pounds. Other models are used for packing bags weighing up to 150 pounds.

**Complete Information and
Recommendations on Request**

FEEDING • MIXING • SIFTING • WEIGHING • PACKING
PACKAGING EQUIPMENT FOR THE PROCESS INDUSTRIES



B. F. GUMP Co.

—Engineers & Manufacturers Since 1872—

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How many of your profit dollars are going down the sewer?



A Sparkler Diatomite filtering system will turn plant water losses into profits

Wasting plant water can cost a surprising amount of money in a short time.

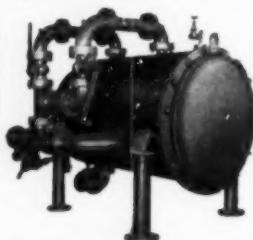
The simplest way to stop this waste is by the re-use of water purified with the new Sparkler large volume diatomite filter; an innovation in water filtration.

Diatomite filtration has in recent years, become the recognized standard procedure in general industrial filtering, and now, the large volume diatomite filter developed by Sparkler opens up a new phase in plant water supply and re-use water not possible with the small size diatomite filters formerly available. Single Model SCJ filter units up to 5,000,000 gallons per day are available.

- ★ Original installed cost is about $\frac{2}{3}$ that of sand filters. Space occupied less than $\frac{1}{2}$ that of sand filters.
- ★ Much less water required to back-wash and clean as compared with sand filters, with attendant economy in water and labor.

Waste water, returned to streams can be cleaned up to meet legal requirements with the Sparkler Model MCR filter with dry disposal of filter cake and residue. A very economical and efficient method of handling the plant effluent water problem.

Model SCJ diatomite water filter. Available in capacities up to 5,000,000 gal. per day in a single unit. Multiple units engineered for larger requirements.

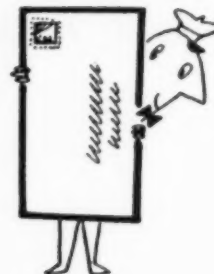


SPARKLER MANUFACTURING CO. MUNDELEIN, ILLINOIS

Sparkler International Ltd., Canadian Plant, Galt, Ontario • European Plant, Amsterdam, Holland

For over a quarter of a century, engineers and manufacturers of a complete line of industrial filtration equipment.

LETTERS TO THE EDITOR



Glenwood Made the Grade

The Glenwood Springs meeting was really exceptional. The papers were good and on subjects of outstanding interest. The plant trips were excellent. The highlight, however, was the spirit of informality . . . Both my wife and I heartily vote for further meetings of this type.

C. H. EVANS

Wilmington, Delaware

Military Service Praised

The fact that a scientist's career is interrupted for 24 months should not markedly lessen his ability to aid in keeping the United States ahead in science and technology, provided he earnestly desires to contribute such aid. In fact, most employers and educators would probably agree that military service, in any capacity, has had some advantageous maturing effect on most individuals.

PFC. ROBERT F. NEU

Headquarters, Chemical Corps
Materiel Command
Baltimore, Maryland

More Symbols

How to provide more symbols for scientific writing aroused much interest in this column several months ago. The problems seemed to be mainly people's resistance to learning or using other alphabets and practical problems in typewriting and printing. One way around these problems would be to use our standard alphabet and turn the letters either on their left side or their right side. In a few cases, as with the letter O, underlining is needed to show on which side the letter is turned. Counting capital and lower case letters, we would have 104 new symbols. Best of all, they can be produced on any standard typewriter, even though our secretaries may need some persuasion.

THOMAS S. MERTES

Sun Oil Company
Marcus Hook, Pa.

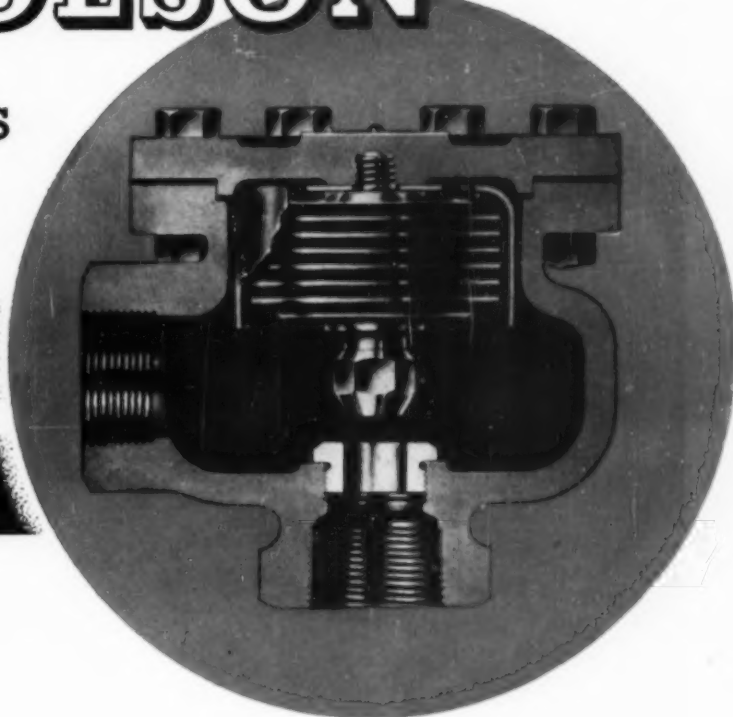
∫ Linotype machines cast their characters only vertically, right side up. To follow
(Continued on page 10)

NICHOLSON

Steam Traps
feature

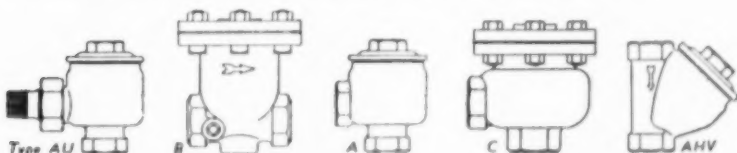
LESS parts

MORE capacity



Note the extreme simplicity of Nicholson industrial steam traps. The heavy-duty bellows integral with valve is the only moving part -- a substantial factor in their low maintenance cost. See also the larger valve orifice. This noteworthy feature results in Nicholson's 2 to 6 times average drainage capacity.

A recent survey showed the features following also to be reasons why plants with standardization-for-economy programs are increasingly adopting Nicholson traps: (1) Operate at lower temperature differential; fast action keeps equipment full of live steam; higher temperatures. (2) No air-binding; eliminate costly fluctuation of operating temperatures. (3) Freeze-proof; freely installed outdoors. (4) No need to change valves for varying operating pressures. (5) Record for low steam waste; as little as 1%.



FIVE TYPES FOR EVERY PROCESS, HEAT, POWER USE

Bronze, semi-steel or cast steel construction. All 5 types have stainless steel valves and seats; bronze, monel or stainless steel bellows. Sizes, $\frac{1}{4}$ " to 2"; pressures from vacuum to 250 lbs.

SEND FOR TRAP CATALOG 953

This 32-page standard reference is complete with installation diagrams as well as charts and formulae for determining proper size of trap.

W. H. NICHOLSON & CO.

TRAPS · VALVES · FLOATS

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MOVE AHEAD...



**"KARBATE"
TYPE "C" PUMP**

Heavy duty model.
2", 3", 4" discharge sizes.
Capacities to 1500 gpm,
heads to 120 feet.
Catalog Section S-7250.

**"KARBATE"
HEAT EXCHANGERS**

Sizes to 162 square feet
from stock; unit areas
to 2300 square feet
based on standard
"Karbate" tube bundles
and covers. Catalog
Sections S-6740 and
S-6840.

**"KARBATE" PIPE
AND FITTINGS**

Light weight, unaffected
by most chemicals,
immune to thermal
shock. Catalog Section
S-7000.

**"NATIONAL" GRAPHITE
COMBUSTION CHAMBER**

Installation in
Phosphoric Acid Plant.
A wide variety of
structural sizes and
shapes are available in
both carbon and
graphite.

CASCADE COOLERS
— Catalog Section S-6820

**HCL
COMBUSTION CHAMBERS**
— Catalog
Section
S-7530

HCL ABSORBERS
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STEAM JETS
— Catalog Section S-7300

...WITH "KARBATE"

BRAND

IMPERVIOUS GRAPHITE PROCESS EQUIPMENT AND "NATIONAL" CARBON AND GRAPHITE PRODUCTS

A wise move in any economy, and one that's practically dictated by present high costs of maintenance and replacement, is the installation of "Karbate" impervious graphite process equipment and "National" carbon and graphite structural shapes *wherever* corrosion is a factor.

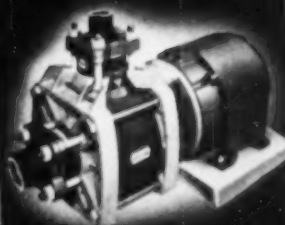
The engineering and technical staffs of National Carbon Company bring to the design and application of their products a record of experience unequalled in the industry. In this diversified line, carbonaceous materials, unique in physical and chemical properties, are combined with proved designs to give you the ruggedness, corrosion resistance and freedom from mechanical difficulty that mean larger, faster return on investment.

Write for
literature!



"NATIONAL" CARBON STRUCTURE

for spray cooling of SO_2 containing gases. Factory-machined parts, field-assembled under National Carbon supervision.



"KARBATE" TYPE "F" PUMP

Motor mounted model. $1\frac{1}{4}$, 2" discharge sizes. Capacities to 200 gpm, heads to 100 feet. Catalog Section S-7250.

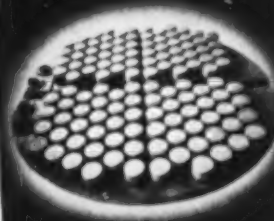
ELECTROSTATIC PRECIPITATOR

constructed of "National" carbon. Answers unusual chemical and structural requirements.



"NATIONAL" GRAPHITE BUBBLE CAPS AND TRAYS

Many other graphite and "Karbate" impervious graphite tower accessories are available. Catalog Section S-7340.



TOWERS

Catalog Section S-7350



GRAPHITE ANODES FOR ELECTROLYTIC PROCESSES

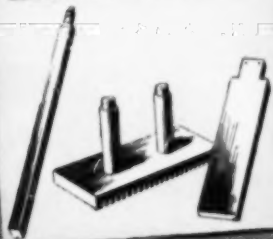


PLATE-TYPE HEAT EXCHANGERS



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New York, Pittsburgh, San Francisco
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Lapp Valves are Solid Porcelain

You need to make no compromise with contamination or corrosion from valves in chemical processing. Lapp valves are of solid Lapp Porcelain, a material unique as a ceramic for industrial scale chemical service. It alone offers the following combination of characteristics and qualities:

PURITY • Lapp Porcelain is a potassium aluminum silicate, made from selected clays, flint and feldspar...has no free iron or other metallic impurity.

NON-POROUS • Complete vitrification of all sections, through firing to 2300°F., provides zero porosity. No dye penetration of body in 100,000 psi test. No chemical can penetrate in service.

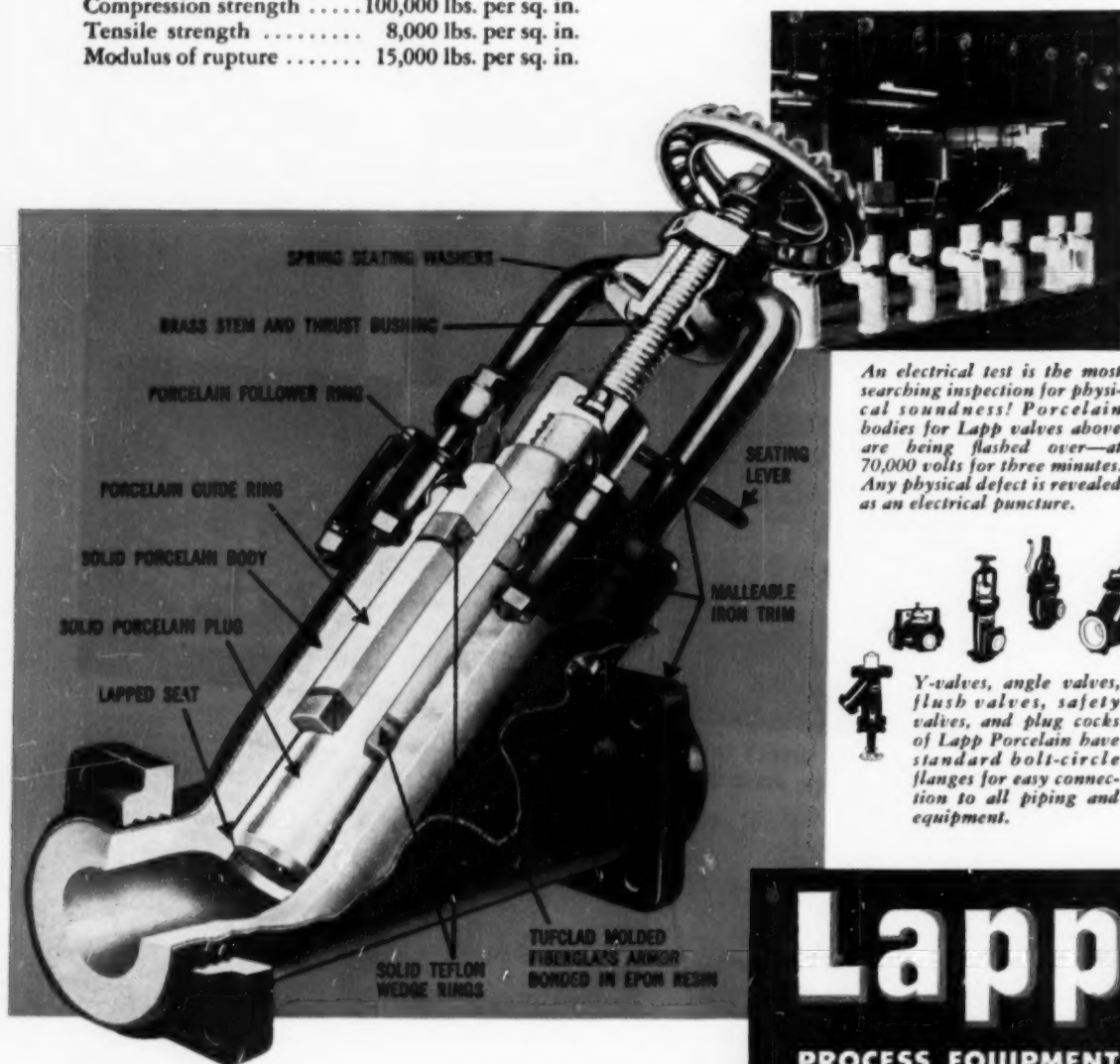
HIGH MECHANICAL STRENGTH

Compression strength 100,000 lbs. per sq. in.
Tensile strength 8,000 lbs. per sq. in.
Modulus of rupture 15,000 lbs. per sq. in.

CHEMICAL RESISTANCE • Lapp Porcelain is unaffected by any acids except HF. It provides years of trouble-free service, handling hot acids in all concentrations, as well as mixed acids and other troublesome combinations.

UNIFORM QUALITY • Lapp Porcelain has been manufactured for 38 years for use in most severe chemical, electrical and mechanical services. Plant facilities include Lapp-patented vacuum processing, deaerating pug mills, two continuous tunnel kilns, and complete chemical, electrical and mechanical test equipment.

Write for bulletin with complete description, characteristics, and specifications. Lapp Insulator Co., Inc., Process Equipment Division, 339 Wendell St., LeRoy, N. Y.



An electrical test is the most searching inspection for physical soundness! Porcelain bodies for Lapp valves above are being flashed over—at 70,000 volts for three minutes. Any physical defect is revealed as an electrical puncture.



Y-valves, angle valves, flush valves, safety valves, and plug cocks of Lapp Porcelain have standard bolt-circle flanges for easy connection to all piping and equipment.

Lapp

PROCESS EQUIPMENT

Chemical Porcelain Valves • Pipe • Raschig Rings
Pulsafeeder Chemical Proportioning Pumps

THESE FLUIDS ARE DIFFICULT TO PUMP

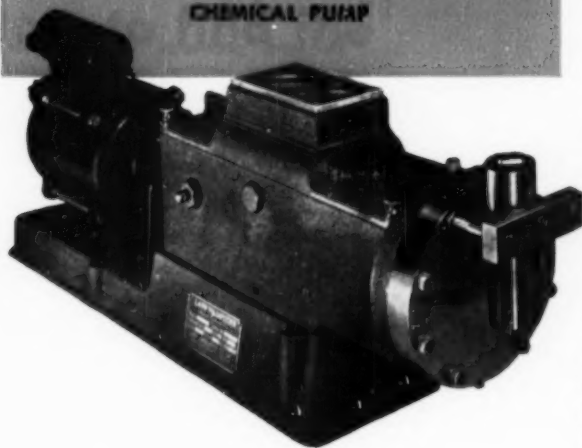
ACETALDEHYDE	SODIUM CYANIDE
ACETONE	SULFUR DIOXIDE
FORMALDEHYDE	TRINITROCHLOROBENZENE
FREON	VINYLDENE CHLORIDE
MERCAPTANS	CHLOROSULFONIC ACID
MERCURY	CHROMIC ACID
MOLTEN METALS	HYDROBROMIC ACID
NAPHTHALENE (Molten)	NITRIC ACID
NITRIC ACID	OLEUM
PHOSPHORIC ACID	OXALIC ACID

PROPIONIC ACID	SALT SOLUTIONS
SULFURIC ACID	SODIUM SILICOFLUORIDE
IODINE	HYDROGEN PEROXIDE
BENZOLCHLORIDE	HYDROCHLORIC ACID
BENZOLTRICHLORIDE	BROMINE TRIFLUORIDE
LIQUID BROMINE	CHLORINE
CHLORACETIC ACID	CHLORINE TRIFLUORIDE
DILUTE ACIDS	FLUORINE GAS
ALUMINUM SULFATE	HYDROFLUORIC ACID
DIATOMACEOUS	HYDROGEN CYANIDE
EARTH SLURRY	HYDROGEN FLUORIDE
FERRIC SULFATE	FLUORINE
SODIUM HYPOCHLORITE	SULFUR DICHLORIDE

THEY ARE HANDLED
SUCCESSFULLY
BY THE

Lapp
PULSAFEEDER

PISTON-DIAPHRAGM CONTROLLED-VOLUME
CHEMICAL PUMP



Not competitive with any pump of more conventional design, the Lapp PULSAFEEDER is a highly specialized, precision, custom-built machine suited to a wide variety of special applications involving controlled-volume pumping of fluids.

Basic feature of Lapp PULSAFEEDER design is its combination of reciprocating piston action (to provide the accuracy of positive displacement) with an hydraulically balanced diaphragm which isolates material being pumped from working pump parts—and, of course, eliminates need for stuffing box or running seal.

Control of pumping rate is achieved at constant pumping speed; variable flow results from variation in piston stroke length—adjustable by hand-wheel, or, in Auto-Pneumatic models, by instrument air pressure responding to any instrument-measurable processing variable.

Justification for this specialized premium construction is evident in the many, and varied, applications in which Lapp PULSAFEEDER alone is able to perform satisfactorily. In fact, the economies of continuous processing, automatic proportioning, feeding and filling in many operations are possible only because of the unusual characteristics and peculiar advantages of Lapp PULSAFEEDER.

In general, use of the Lapp PULSAFEEDER is indicated for continuous (or intermittent) pumping, at accurately controlled volume, of fluids which cannot be satisfactorily exposed to conventional pistons, cylinders and stuffing box packing—because of the corrosive action of chemicals being handled and/or need for protection of product against contamination.

Lapp Bulletin 660 shows typical applications and flow charts. It describes and lists specifications of models over a wide range of capacities and special constructions. Also included is an Inquiry Data Sheet, from which we can make specific engineering recommendations for your processing requirement. For your copy write Lapp Insulator Co., Inc., Process Equipment Div., 403 Wilson St., Le Roy, N.Y.



"J.B. bothers less with details since he started using TEFLON* made by ETHYLENE "

* DuPont trade name for tetrafluoroethylene resin**

This amazing material is chemically inert, has excellent dielectric properties, resists heat and cold, is nonadhesive, and possesses great flexural strength. We make it in a great variety of sizes, of the finest quality, and for quick shipment. May our experts help you?

Write for Catalog C54

** Converted by Ethylene into the best basic forms in the world, undoubtedly.***



EXTRUDED OR MOLDED RODS, TUBES, AND
SPECIAL SHAPES. NON-POROUS SHEETS

*** We think.



"Pioneers and Specialists in TEFLON products"

ETHYLENE CHEMICAL CORPORATION

245 Broad St. • Summit, New Jersey

LETTER TO THE EDITOR

(Continued from page 4)

this suggestion would require hand setting of individual letters—a very expensive and time-consuming operation. [Editor]



NOTED AND



Atoms for the People

There is one important fact that the government administrator must remember. This is that no atomic energy information inherently belongs to the government. The government is the Trustee, but the information really belongs to the people of the United States. They paid for its accumulation, and—except for the overriding reason of national security—all of it would be in the public domain where it would be available to anyone wishing to use it. Information accumulated or appropriated by the government does not automatically take on a sacrosanct character that the government administrator must fight to protect what may be erroneously considered the contaminating influence of competitive industry. After all it was our total economic system under competitive enterprise that provided the money that built the program that produced the information in the first place.

T. Keith Glennan

President, Case Institute of Technology

Pressure Groups

The term "pressures," as I use it, denotes groups having special interests. The main flaw in the armor of these special interest groups is that their vision and thoughts are limited to their particular part in the overall picture, or, from a selfish interest, they fail or refuse to accept the overall picture as it exists. It is clearly a case of failure to see the forest for the trees.

Pressures always occur in connection with any program affecting the lives of people. The experience of the Selective Service System from 1940 to date has been no exception. It is surprising that the influences exerted upon the System during World War II, the Korean hostilities and the present operation have not been more unreasonable than they have been, and that they have not worked greater havoc than they have.

There are numberless occasions under which criticisms are leveled at the Selective Service System, from the Director to local board members, because of

(Continued on page 14)



This Tolhurst Centrifugal with "all-speed" drive is used to determine best centrifuging speeds for photographic and fine chemicals. Photo courtesy of Ringwood Chemical Company, Ringwood, Illinois.

How to find the BEST CENTRIFUGAL SPEEDS FOR YOUR PRODUCTS

Determining the most efficient centrifuging speeds can help you lower manufacturing costs and increase production. For only the *right* speeds will make the proper degree of separation in the shortest time.

Tolhurst's "all-speed" hydraulic drive helps you establish the best basket speeds for loading, extracting, washing and unloading. You can select *any* speed from 0 to maximum RPM. Your tests show you which speed performs each operation most efficiently.

Or, do you have the problem of processing many different materials that have dissimilar filtering and washing characteristics? With "all-speed" drive, you can process them all in the same Tolhurst Centrifugal.

You simply turn a handwheel to change speed. A tachometer indicates basket speed at all times. "All-speed" drive can now be furnished on any Tolhurst Centrifugal. Available with baskets from 12" up to 108" in diameter. Construction can be of steel, steel rubber covered, stainless steel or other corrosion-resistant materials. For full information, write for illustrated catalogs.

FREE CENTRIFUGING CALCULATOR — A new slide rule for quickly calculating centrifugal force is yours for the asking. Just mail coupon below.

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- ☐ Send new free centrifugal force calculator
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DIVISION OF AMERICAN MACHINE AND METALS, INC.
EAST MOLINE, ILLINOIS

SAFE CONTROL

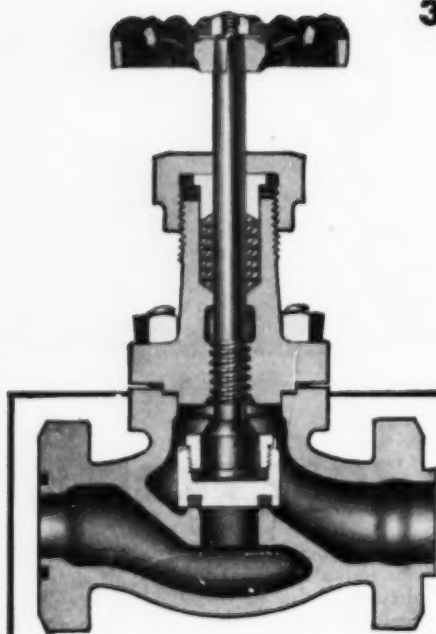
for ammonia and other
hard-to-handle fluids

CRANE

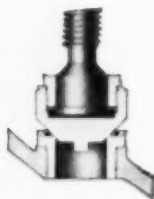
300-pound heavy-duty all-iron valves

Put these Crane valves to the test—use them for ammonia, air, oil, gas, caustic solutions, chlorinated compounds, alcohols—for chemicals and process work. Their rugged bodies of Ferrosteeel (35% stronger than cast iron)... their precision seating designs... the unusually deep stuffing box and high-grade packing... the sweeping interior body contours... assure the safety and lasting service you want.

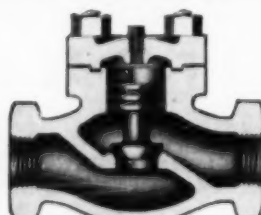
The line includes *bolted bonnet globes* and angles with choice of disc, *union bonnet globes* and angles with plug-type disc, lift checks, expansion valves, relief valves, liquid gauges—and all the fittings, flanges, return bends and other specialties for a complete Crane Quality installation. Check with your Crane man.



Cross-section bolted bonnet Globe, with flanged ends and special lead-faced disc. Sizes 1/4 to 4-inch.



Bolted bonnet Globes also available with steel disc and seat where high temperatures or corrosion prohibit use of lead.



Cross-section, Lift Check with bolted cap, and cushioned disc action which increases valve life. Sizes 1/2 to 2-inch.



New 6-page folder AD1977 catalogs this complete Crane line. Write direct, or ask your Crane Representative.

THE BETTER QUALITY... BIGGER VALUE LINE... IN BRASS, STEEL, IRON

CRANE VALVES

CRANE CO., General Offices: 836 S. Michigan Ave., Chicago 5, Illinois
Branches and Wholesalers Serving All Industrial Areas



for the
**THRIFTY
BUYER**

VALVES • FITTINGS • PIPE • PLUMBING • HEATING



wherever
corrosives
flow...

try NEW DUR-ACE PIPE

a tough, corrosion-resistant plastic
with a good cost factor

Dur-Ace is a new corrosion-resistant, rigid plastic pipe with exceptional impact strength and toughness . . . good for handling most corrosive fluids in your plant at moderate temperatures and pressures . . . with low first cost and long life.

Light in weight, Dur-Ace is odorless, tasteless, and non-contaminating. It maintains good strength, rigidity and chemical resistance from minus 40 deg. F. to 170 deg. F. As shown below, it handles all types of chemicals except a few strong acids and organic solvents. Dur-Ace is corrosion-resistant on the *outside* too, and saves the cost of painting. Electrolytic corrosion and bacteria have no effect on Dur-Ace, so it's excellent for underground lines handling water, brine, petroleum, natural gas, etc.

Successful field installations of thousands of Dur-Ace molded fittings have been made. We have job-proved performance data covering a wide variety of corrosives. Dur-Ace is available in pipe sizes from 1/2" to 2", Standard and Extra Heavy, with a wide variety of fittings.

Dur-Ace is the eighth basic type of corrosion-resistant pipe available from ACE . . . including materials for high pressures, high temperatures, strong acids, organic solvents, etc., and pipe sizes to 24" and above. Consult ACE first with any corrosion problem.

CHEMICAL RESISTANCE AT 77 DEG. F.

SATISFACTORY

Acetic Acid 10%
Hydrochloric Acid 30%
Sulphuric Acid 50%
Ammonium Hydroxide 28%
Calcium Hydroxide
Sodium Hydroxide 20%

Ferric Sulphate

Salts of Calcium,
Sodium, Potassium,
Ammonium, etc.
Bleaches
Most Plating Sols.
Oil (SAE 10-30)

LIMITED

Formic Acid 20%
Hydrofluoric Acid 10%
Nitric Acid 10%
Phosphoric Acid 50%
Alcohols
Vegetable Oils

UNSUITABLE

Acids stronger than
listed at left
Aromatic Hydrocarbons
Chlorinated Solvents
Esters
Ketones

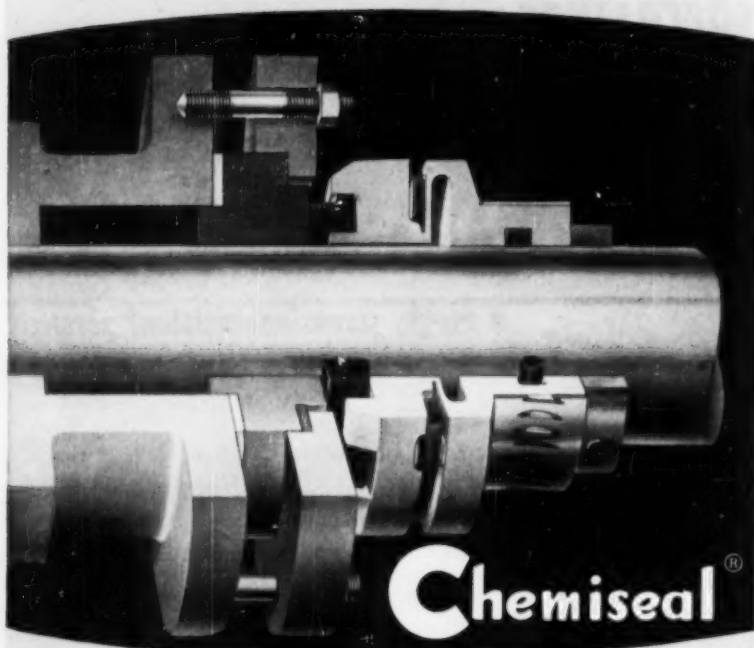


WRITE FOR BULLETIN 80A TODAY.

ACE rubber and plastic products

AMERICAN HARD RUBBER COMPANY
93 WORTH STREET • NEW YORK 13, N. Y.

Here is the Shaft SEAL you have been wishing for



Chemically Impervious TEFLON Balanced Bellows Design

Three years of actual field tests have proven that Chemiseal external mechanical seals last longer and give unsurpassed performance under a wide variety of chemical service conditions—handling acids, alcohols, alkalis, hydrocarbons, and related chemical compounds including abrasive slurries and tarry material (with provisions for flushing).

Combining the Bellows design, which provides pressure balance so essential for long leak free service, with duPont TEFLON the wonder plastic for immunity to corrosion and contamination—United States Gasket engineers have produced a mechanical seal which makes "sealing" simple and economical for the process industries.

FEATURES

• **CHEMICALLY IMPERVIOUS** TEFLON Bellows section. A selection of seal face

materials dependent upon medium and service requirements.

• **SEAL ROTATES WITH SHAFT** Only bearing surface is between precision ground rotating and stationary seal faces. Low friction load on shaft. Lower power cost. Drop tight service.

• **NO SCORING OF SHAFTS** and Chemiseals work satisfactorily on shafts previously scored by other seals or packing.

• **LIFE EXPECTANCY** many times that of other seals or packing.

• **PRESSURES** at the seal up to 100 psi at 75°C or 75 psi at 100°C.

• **SIZES** from $\frac{3}{8}$ " to 2 $\frac{3}{4}$ ". Other sizes for special applications.

• **MAXIMUM LENGTH**, all seals 2 $\frac{3}{4}$ ".

Write for Bulletin No. MS-954.



NOTED AND QUOTED

(Continued from page 10)

actions taken to administer the law. It is always a matter of regret that interested groups, in their hopes, think of the law as they would wish it to be rather than as it is.

Local board members, all unpaid, with a dozen years of experience and considerable knowledge of the capacities, the virtues, and the shortcomings of the skilled, the unskilled, the technical, the professional, and the farmer, cannot understand the criticisms leveled at them by other groups of citizens who have special rather than general interest in the public good, and while charging the local board members with scientific naiveness exhibit startling unfamiliarity with our Nation's laws.

Major Gen. Lewis B. Hershey

Inheriting America!

The future of our civilization depends upon the ability of our engineers and scientists to disseminate information representing the true technological facts, thus promoting a better understanding of the role and the place of science and technology in our national life. It could be that some of us may live to see the day when a nation's true wealth will be measured in terms of its men and women of science rather than in terms of its natural resources.

To the students in chemical engineering, your future and the future of this nation which begins today—that future in which we all must live beginning now—will be the product of the thinking and accomplishment of the men and women of your generation, because in a few short years you will take over the management of this great American economy, and when you inherit America, it will be of your own making. The obvious reason, therefore, why you are students of this great institution of learning today is to better equip and qualify yourselves to accept this heritage and perpetuate it for the benefit of your posterity and civilization.

Howard E. Fritz
B. F. Goodrich Company

Nuclear Energy and You

At present, atomic energy is a Government-owned industry. This departure from the normal pattern of industrial enterprise in the country was not undertaken capriciously or with intent to alter our institutions. It was deemed necessary to cope with the unique and un-

(Continued on page 22)



Note the compactness of Commercial Solvents Corporation's new 225-ton-per-day Stengel Process Ammonium Nitrate Plant at Sterlington, La.

Crystalline
AMMONIUM NITRATE
FERTILIZER
in one simple step
THROUGH C & I



Actual Crystal Size

C & I can now license the new CSC Stengel Process to users and furnish complete plants to produce crystalline ammonium nitrate (33.5% N). Due to simplicity of design, capital and operating costs of these plants are substantially less than similar plants using prilling and granulating processes.

FREE FLOWING In this process, ammonium nitrate of any desired particle size can be produced in a single step. Actual spreading tests in the field have proved that this

crystalline ammonium nitrate is completely free flowing with a more controllable flow than competitive products.

NON-CAKING This new exclusive process produces a very low-moisture material permitting satisfactory long term storage. The coating on the particles reduces to an absolute minimum the tendency of ammonium nitrate to absorb moisture.

C & I ammonium nitrate plants using the Stengel Process can also produce limed ammonium nitrate (20.5% N) and ammonium nitrate sulfate (26.5% N). These plants are constructed at a fixed price with production and efficiencies guaranteed.

C & I can also furnish nitric acid and complex fertilizer plants (using PEC process) on this same basis.



Solidified ammonium nitrate sheet is broken into small bits by rotating spoke shaft.

Specialists in



Processing Ammonia

THE CHEMICAL AND INDUSTRIAL CORP.

CINCINNATI 26, OHIO

HUNDREDS OF TIMES FINER

THAN THE FINEST WIRE MESH . . . A CELITE FILTER CAKE!



With *Celite Filtration* you are assured perfect clarity

HERE is a clarification method which can remove even the finest suspended solids . . . a Celite* Filter Cake contains more than 2,500,000 filter channels per square inch of surface. Here, too, is a method so flexible that it permits the right balance of fast flow rate and high capacity, with the degree of purity and clarity required.

Celite powders may be used with any type of conventional filter. Only 2 simple steps are required. First, a "pre-coat" of Celite is deposited on the filter medium. Second, small amounts of Celite are added to the solution, to form a con-

tinuously fresh filter surface. To meet different filtration requirements, Celite is available in nine standard grades of microscopically controlled particle size. Utmost uniformity is assured by exclusive processing techniques.

The extraordinary efficiency and flexibility of Celite Filtration have made it the standard for entire industries. For perfect clarity in food products such as jellies, sugar, wine, beer . . . for highest purity in antibiotics . . . for removal of impurities from chemicals, petroleum, dry cleaning solvents . . . Celite offers unequalled advantages.

If you want to improve your present filtration system or find an economical way to utilize filtration in your processing, investigate the Celite method now. One of the Johns-Manville Celite Filtration Engineers will gladly discuss your problem. These men are backed by complete technical services and the Johns-Manville Research Center, largest laboratory of its kind in the world. For further information write Johns-Manville, Box 60, New York 16, N. Y. In Canada, 199 Bay Street, Toronto 1, Ontario.

*Celite is Johns-Manville's registered Trade Mark for its diatomaceous silica products.



Johns-Manville **CELITE** FILTER AIDS

WHEN CORROSION IS CRITICAL

Optimum tube for the job = $\left[\frac{(\text{pressure}) \times (\text{length}) \times (\text{allowable stress})}{(\text{flow rate}) \times (\text{cost/ft})} \right] \times (\text{Ni} + \% \text{Cr, temp, atmos})^2$

Tube Selection Cannot be Reduced to a Formula —even a complicated one

Selection of the proper grade of stainless steel for a particular application is a relatively complex problem and involves manufacturing, metallurgical, chemical and economic considerations. Although it is complex it has been made easier by industrial research. Data accumulated through years of research and experience gained in helping to solve varied application problems are now available to guide the user in the solution of his present problems.

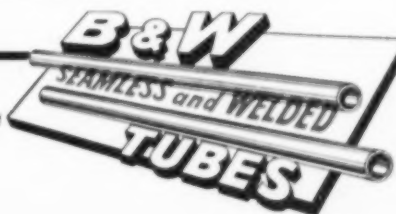
It is practically impossible to list all the media in which stainless steels will resist corrosion. It is even more difficult to enumerate all the conditions under which the stainless steels will resist effectively the corrosive effects of such media. Frequently, a relatively minor contami-

nant, when combined with the main reagent, will cause a more detrimental corrosive action than the latter by itself. This is particularly true of iron salts which, in the presence of chlorides, often prove to be a very potent corrodent, producing pitting.

It is always advisable to test a sample under actual operating conditions, especially before extensive untried installations are made. Proper tube selection starts with expert opinion, available to you through Mr. Tubes, your nearby B&W Tube Representative. There is no substitute for the kind of experience with pressure tubing problems you'll find at B&W. Ask Mr. Tubes for help in matching tubes to jobs.

THE BABCOCK & WILCOX COMPANY TUBULAR PRODUCTS DIVISION

Beaver Falls, Pa.—Seamless Tubing; Welded Stainless Steel Tubing
Alliance, Ohio—Welded Carbon Steel Tubing



TA-4061(P)

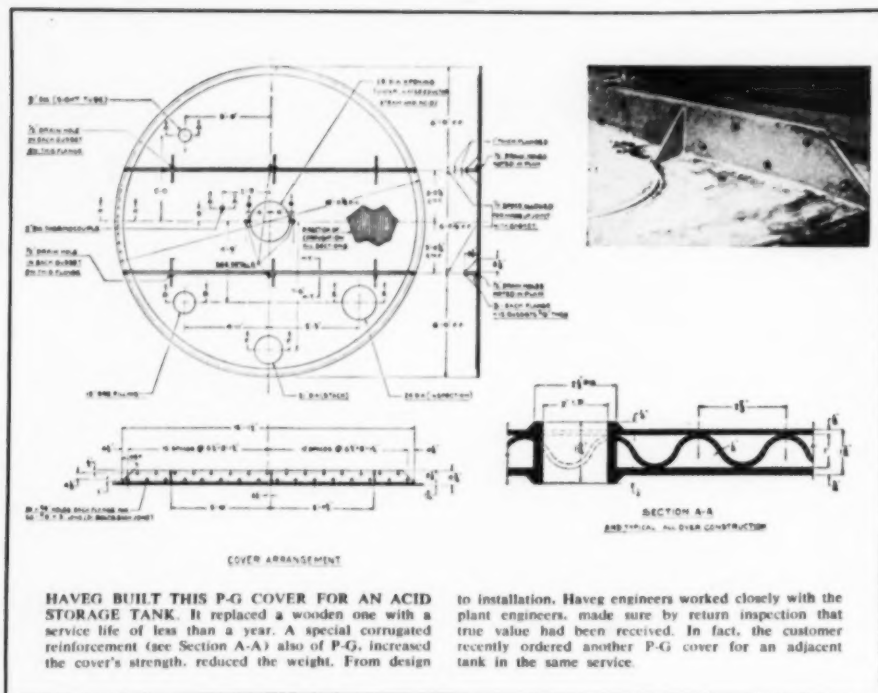
consult **HAVEG** . . . America's first molder of corrosion-resistant plastic equipment



P-G TANKS for metal finishing withstand acid attack, are non-conductors of electricity, can take hard knocks.



P-G FUME DUCT is molded into complete fume removal systems. Duct is easily installed, does not require elaborate supports.



HAVEG BUILT THIS P-G COVER FOR AN ACID STORAGE TANK. It replaced a wooden one with a service life of less than a year. A special corrugated reinforcement (see Section A-A) also of P-G, increased the cover's strength, reduced the weight. From design

to installation, Haveg engineers worked closely with the plant engineers, made sure by return inspection that true value had been received. In fact, the customer recently ordered another P-G cover for an adjacent tank in the same service.

FOR COOLING TOWERS • FUME DUCT • TANKS • COVERS • LININGS • PIPE of **P-G** laminated polyester glass

Both users and manufacturers of cooling towers, and similar structures subject to corrosive liquids and gases, can profit by relying on the accumulated engineering skill of the Haveg Corporation, which is now making polyester glass laminated plastic equipment.

Polyester glass is lightweight, low-cost, easy to fabricate and install. It resists many corrosives. Haveg P-G (polyester-glass) products are satisfactory for continuous operation at temperatures about 200°F., and for intermittent service as high as 240°F.

Molding plastics into corrosion-resistant equipment is not a new venture for Haveg. Over twenty years ago Haveg introduced a new plastic material . . . Haveg . . . made from acid-digested asbestos mixed with special Haveg resins. Haveg has been made into the biggest molded plastic tanks in the world, into a 200' high fume stack, into giant petrochemical installations.

Like any other construction material, Haveg 41 and 60 and the new P-G materials sometimes present problems in design, manufacture, installation, or economics of selection. In the end, the purchaser must rely on the experience and reputation of the supplier. So Haveg makes these promises:

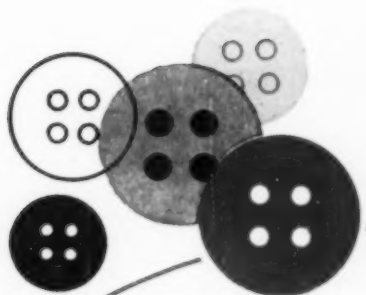
1. Polyester glass will be recommended and supplied only after complete testing and full consultation with your plant engineers.

2. Haveg will use its broad experience in fighting corrosion to tell you if P-G is the best material. A reference file of installations plus systematic progress reports where available will be a valuable source of information.

Haveg P-G is new. It promises good dividends in many applications. But it calls for close cooperation between Haveg and the user. Call the Haveg sales engineer listed. Tell us your problem . . . together we will find if Haveg P-G fits your needs!

ATLANTA, Exchange 3821 • CHICAGO 11, Delaware 7-6088
CINCINNATI 36, Sycamore 2600 • CLEVELAND 20, Washington 1-8700
DETROIT 39, Kenwood 1-1785 • HOUSTON 4, Jackson 6840
LOS ANGELES 14, Mutual 1105 • SEATTLE 7, Hemlock 1351
ST. LOUIS 17, Mission 5-1223 • WESTFIELD, N. J., Westfield 2-7383

HAVEG CORPORATION
NEWARK 3, DELAWARE
FACTORY: WILMINGTON 8, DEL. • Wilmington 3-8884
A SUBSIDIARY OF CONTINENTAL-DIAMOND FIBRE CO.



BAKER PERKINS

SIZE 14 JNM2 UNIVERSAL MIXER

—uniformly blends special vinyl compounds

for Auburn Button Works, Inc., Auburn, N.Y.

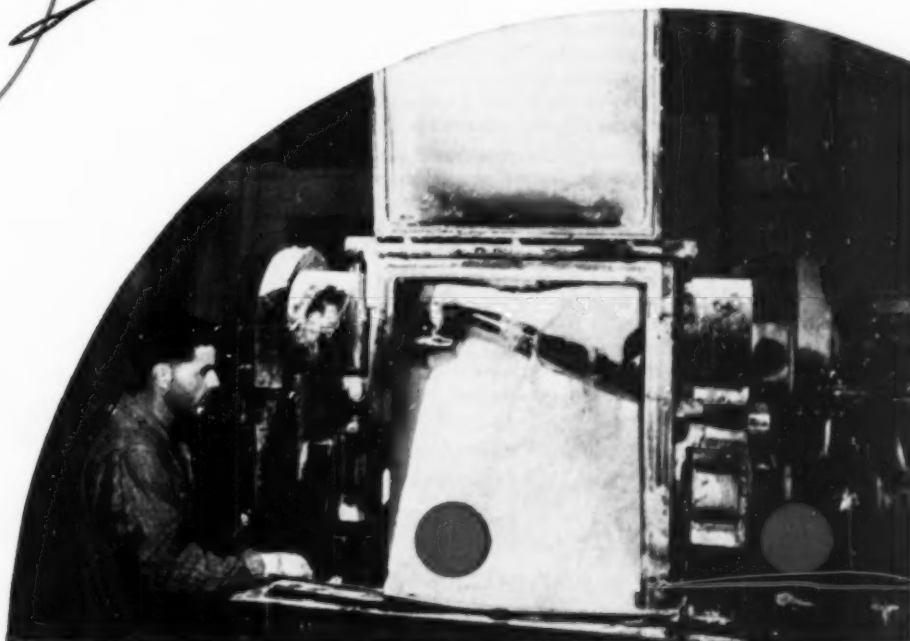
As an intermediate processor of raw materials for plastics fabricators, the Extrusion Division of Auburn Button Works in Auburn, New York, compounds and blends a wide variety of special vinyl plastic mixtures for its many customers. Thorough mixing and intensive kneading of the materials is necessary to insure a uniform blend with high tensile strength, good surface quality, retention of heat and light stability and other characteristics important in the finished extrusion. To obtain these characteristics, Auburn employs a specially designed Size 14 BAKER PERKINS JNM2 Universal Mixer with a working capacity of 50 gallons and a total capacity of 75 gallons. This machine is equipped with a trough shell of #304 stainless steel and is jacketed for 80 lbs. steam pressure. It has cast sigma blades with dispersion faces, cored for steam, and is driven by a 20 h.p., 900 rpm. motor.

BAKER PERKINS Universal Mixers are adaptable to virtually every mixing and kneading operation from very light to heavy duty, handling mixtures ranging in consistency from dry powders to stiff plastic masses. For complete information about Universal Mixers and other B-P equipment for the chemical processing industries, consult a BAKER PERKINS sales engineer or write us today.

289

BAKER PERKINS INC.

**CHEMICAL MACHINERY DIVISION
SAGINAW, MICHIGAN**



High-temperature Alloys now Melted and Cast in Stokes High-Vacuum Furnaces

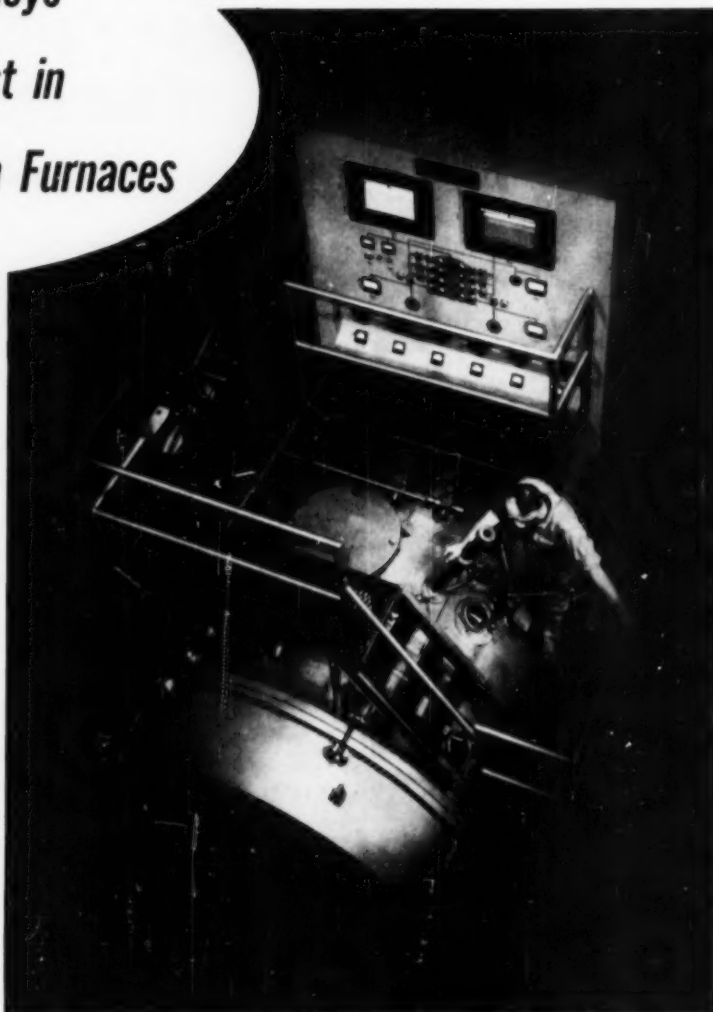
Vacuum furnace melting and casting is the economical method for producing many new metals, with greatly improved properties. Alloys that can stand up in rocket engine combustion chambers and advanced jet engine turbines, metals essential for the construction of nuclear reactors, still other high-purity metals with properties not previously attainable . . . these are just a few of the more than thirty new elements vacuum processing has added to the industrial spectrum.

Vacuum-melted high alloy steels have greater tensile, yield, and impact strengths than conventionally-processed metal, plus greater stress-rupture strength at elevated temperatures, less creep, less brittleness. High-purity iron, processed in vacuum, has 60 to 75% greater stress-rupture strength and 400% more elongation than conventional metal. In anti-friction bearings, vacuum-processed steel has shown an increase of 300% or more in fatigue strength, and given a whole new perspective to the subject of wear-resistance.

Moreover, vacuum processing of alloys conserves critical hardening elements, since there is minimum loss of these metals during melting. More usable metal is obtained from each melt, and virtually all of the scrap can be salvaged by vacuum melting.

STOKES is building vacuum furnaces to process these high-purity metals in quantities up to 2000 pounds, and planning 5000-pound units. STOKES vacuum furnaces reflect the practical experience accumulated in fifty years of building vacuum equipment. An interesting NEW brochure is ready for mailing on request!

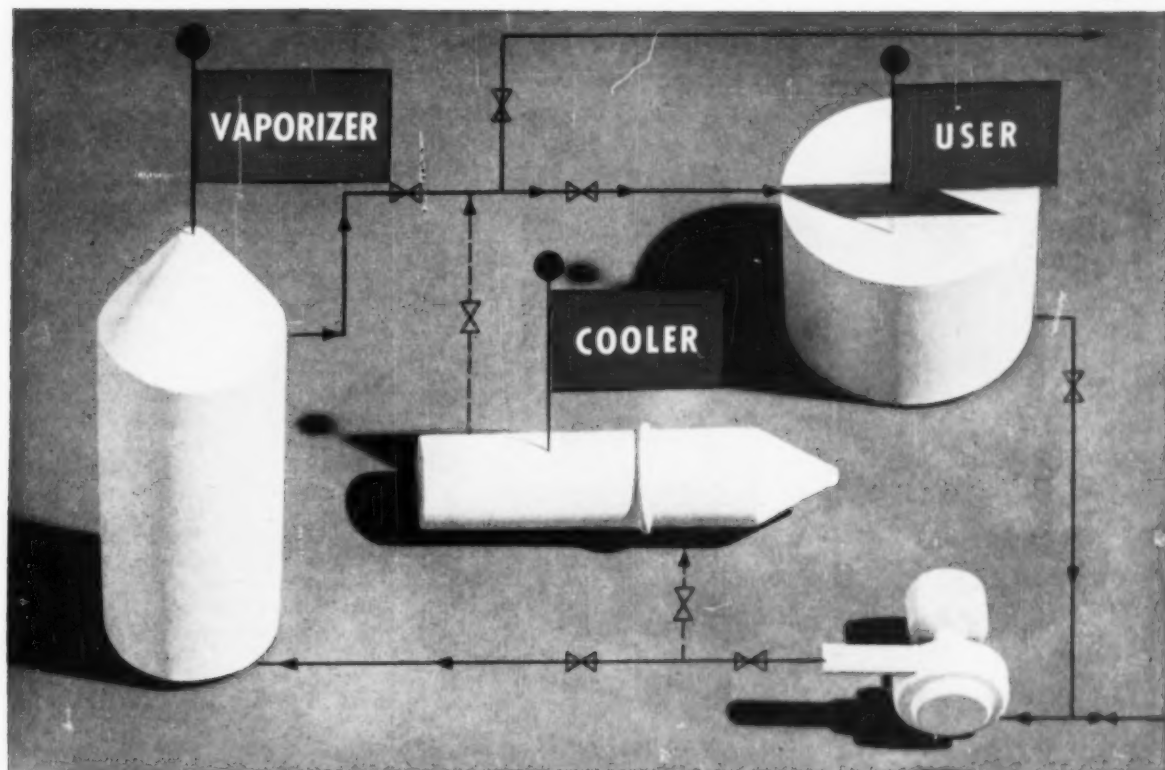
F. J. STOKES MACHINE COMPANY
PHILADELPHIA 20, PA.



A Stokes high-vacuum melting furnace of 1000-pound capacity at Utica Drop Forge & Tool Corporation, Utica, N. Y. The furnace is to be used for the melting and casting of high-temperature alloys for jet engine rotor blades.

STOKES

STOKES MAKES: High Vacuum Equipment, Vacuum Pumps and Gages / Industrial Tableting, Powder Metal and Plastics Molding Presses / Pharmaceutical Equipment



ALTERNATE HEATING AND COOLING

in the same equipment
is practical with

DOWTHERM

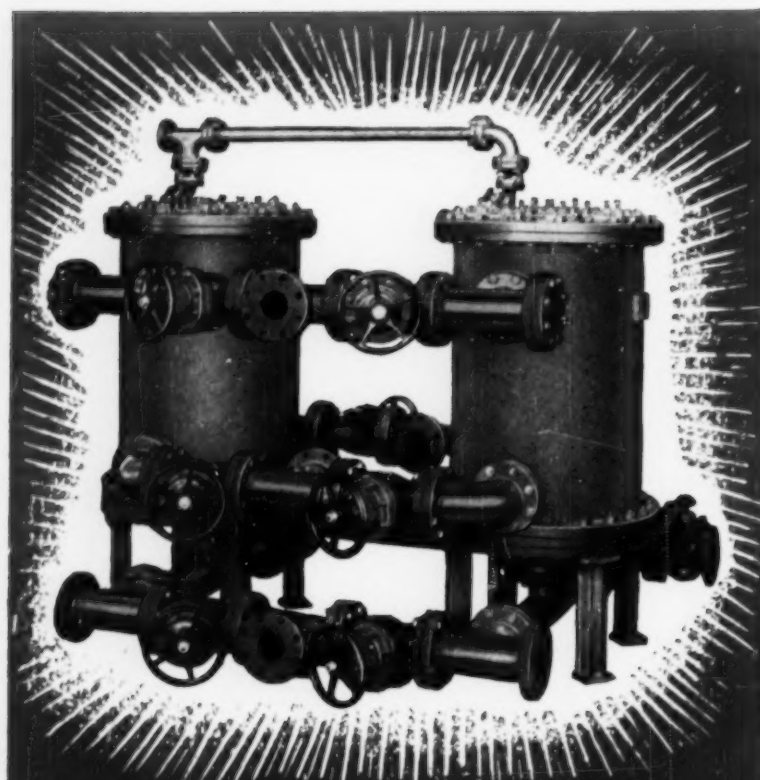
Highly efficient Dowtherm[®], used as a vapor for accurate high temperature process heating, may be utilized as a liquid when your processing cycle calls for alternate heating and cooling in the same equipment. This provides a versatile system in which a series of accurately controlled temperatures is possible without transferring material being processed. Dowtherm as a liquid coolant is particularly valuable in reactions where it is necessary to absorb heat at high temperatures.

If your process calls only for heating, a Dowtherm vapor system will provide up to 750°F. heat, precision controlled by simple pressure regulation. Since Dowtherm does not contain any minerals, there are no costly scaling problems in your vaporizer or processing equipment . . . only a minimum of routine maintenance is required.

Dowtherm was created by the Dow research team for the chemical, petroleum, paint, food and other process industries—has helped to increase production and even made possible new products. To learn how you can gain these benefits write to THE DOW CHEMICAL COMPANY, Midland, Michigan, Dept. DO 877A-1.

you can depend on **DOW CHEMICALS**





Several years ago, the R. P. Adams Company, Inc., was asked to help solve a filtering problem for one of the world's largest chemical firms. After a study of the problem, two Adams CFR-5 filters were delivered.

**here's
Proof Positive**

ADAMS FILTERS

**can
SAVE YOU MONEY!**

Several years ago, the R. P. Adams Company, Inc., was asked to help solve a filtering problem for one of the world's largest chemical firms. After a study of the problem, two Adams CFR-5 filters were delivered.

RESULTS? There can be no question about results, for the two additional filters shown above were recently ordered . . . "to be identical to the two previously purchased."

If you have a filtering problem, it will pay you to find out how R. P. Adams Filters can save you money. Write today and give us full details of your problem, or ask for our Bulletin 431.

R. P. ADAMS CO., INC.

240 East Park Drive

● Buffalo 17, New York



NOTED AND QUOTED

(Continued from page 14)

familiar characteristics of atomic energy and because its products then went almost entirely into our military arsenals. Continuance of complete Government dominance into the period of major peacetime applications, involving as it would a basic change in the fundamental roles of Government and of private individuals and firms, could produce a change in our society as significant in its way as any that might accrue from the technical novelty of nuclear power.

In order that the principal effect of realizing nuclear power may be to confirm and strengthen rather than to change our economic institutions and our way of life, we believe that nuclear power as it becomes economically attractive, should be integrated into the existing power economy of the nation; that nuclear power should be produced and distributed by the private and public power systems and not by the Commission.

Sixteenth Semiannual Report
Atomic Energy Commission

MARGINAL NOTES

Industrial Stoichiometry, 2nd edition. Warren K. Lewis, Arthur H. Radasch, and H. Clay Lewis, McGraw-Hill Book Co., Inc., New York (1954), 429 pp. \$7.50.

Reviewed by Warren L. McCabe, Dean, Polytechnic Inst. of Brooklyn, Brooklyn, N. Y.

The first edition of this well-known text was published twenty-eight years ago. The new edition, like the old, carries the sub-title "Chemical Calculations of Industrial Processes," which is an accurate specification of the book's contents.

For those unfamiliar with 1st edition, "Industrial Stoichiometry" presents an intensive application of simple basic laws in the calculation of industrial processes. Elementary chemistry, gas laws, physical and chemical equilibria, and material and heat balances are used extensively. The core of the treatment is the far-reaching principle that input equals output. The method of the treatment is by a combination of factual background and carefully planned and thoroughly explained numerical examples. The new edition is more than twice the size of the old and contains the material in the first edition plus new

(Continued on page 28)

SULPHUR GOES ATOMIC

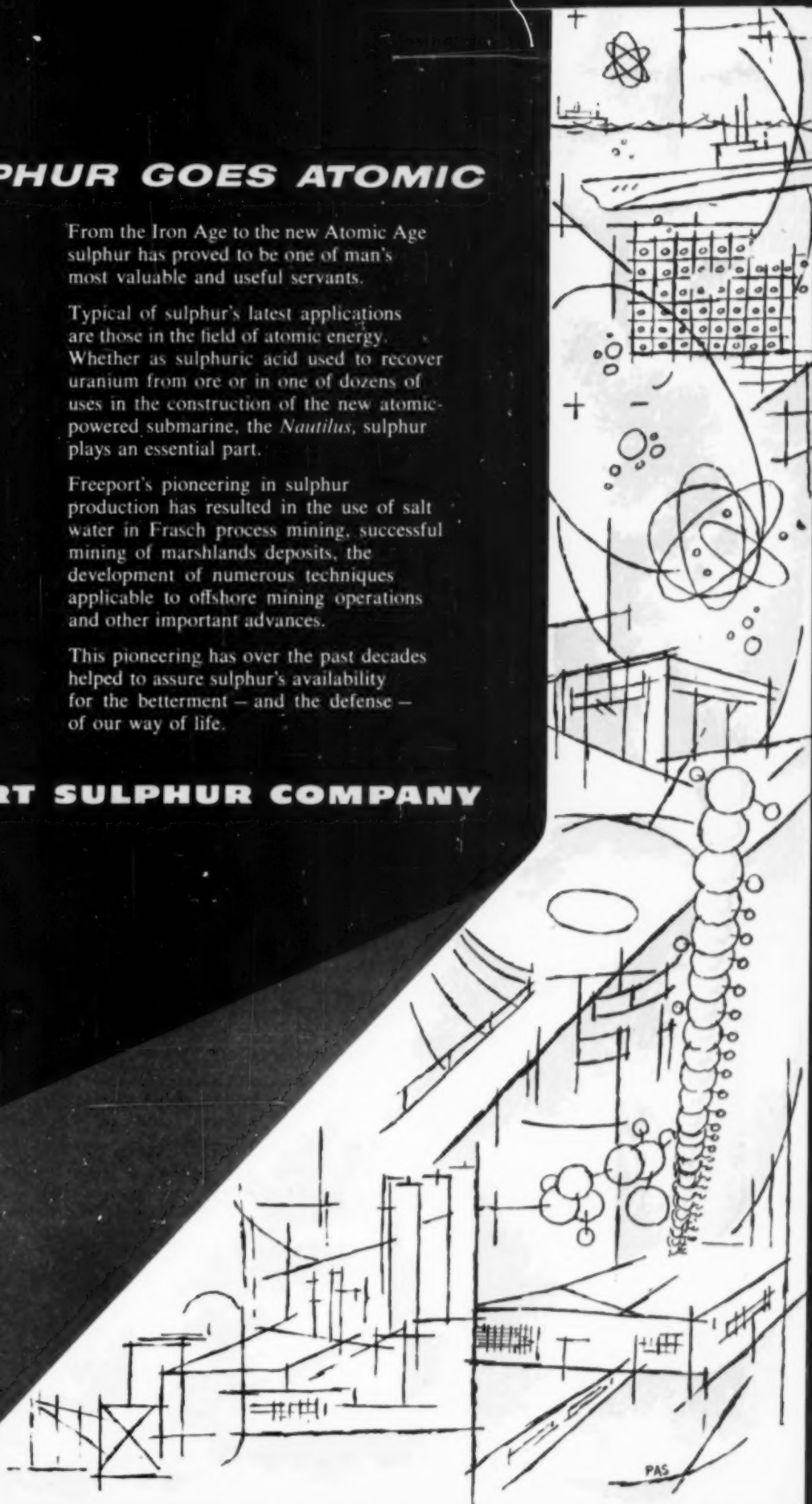
From the Iron Age to the new Atomic Age sulphur has proved to be one of man's most valuable and useful servants.

Typical of sulphur's latest applications are those in the field of atomic energy. Whether as sulphuric acid used to recover uranium from ore or in one of dozens of uses in the construction of the new atomic-powered submarine, the *Nautilus*, sulphur plays an essential part.

Freeport's pioneering in sulphur production has resulted in the use of salt water in Frasch process mining, successful mining of marshlands deposits, the development of numerous techniques applicable to offshore mining operations and other important advances.

This pioneering has over the past decades helped to assure sulphur's availability for the betterment — and the defense — of our way of life.

FREEPORT SULPHUR COMPANY



Some of the functions that have been successfully performed by Sandvik Conveyors

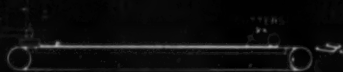
WITH A SANDVIK WATER-BED CONVEYOR YOU CAN:



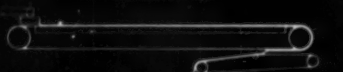
COOL AND CONVEY



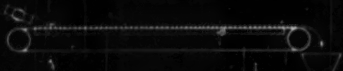
REGULATE THICKNESS WHILE COOLING
(ANY THICKNESS UP TO 1" CAN BE COOLED)



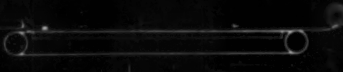
CUT MATERIAL TO DESIRED SIZES
WHILE COOLING



COOL AND STRIP OFF GELATINOUS
MATERIALS IN SHEET FORM



COOL LOOSE AND PULVERIZED
MATERIALS



COOL SOLIDS IN SHEET FORM

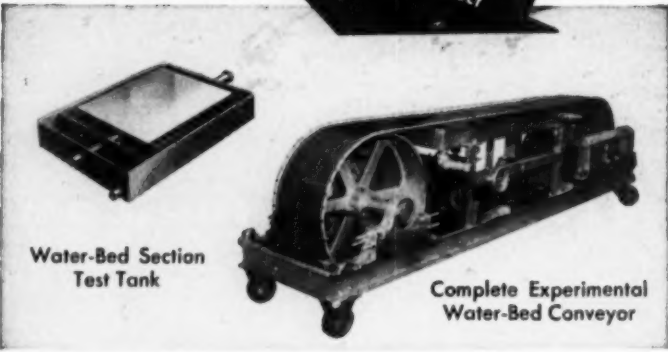


COOL MATERIAL IN LAYERS

HOW CAN SANDVIK'S CONTINUOUS STEEL-BELT COOLER Improve YOUR production?



HERE ARE TWO WAYS
To "Pre-Test" Sandvik's
Steel-Belt, Water-Bed Conveyor
With Your Own Product



Water-Bed Section
Test Tank

Complete Experimental
Water-Bed Conveyor

With one of these experimental units you can find out how Sandvik's patented water-bed conveyor can make your processing more automatic.

A small scale trial in your plant will enable you to determine cooling rates and other pertinent data. You will see for yourself the extraordinary cooling capacity of this conveyor combined with the advantages of the steel belt.

How The Water-Bed Conveyor Operates—The loaded steel band "floats" along on an open trough of circulating water. The water pressure assures 100% coolant contact with the belt. The trough is so designed that no water can get on top of the belt.

Experimental water-bed units are available on request. Sandvik's engineering department will help you decide which test unit is best suited for your purpose. Write, wire or 'phone for complete details.

SANDVIK STEEL BELT CONVEYORS
Division Sandvik Steel, Inc.
111 Eighth Ave., New York 11, N. Y.
BRANCH OFFICE:
230 N. Michigan Ave., Chicago 1, Ill.
IN CANADA: SANDVIK CANADIAN LTD.,
5675 Royalmount Ave., Montreal 16, P. Q.
*Manufacturers of Steel Belt Conveyors for
Over Thirty Years*



SS-64

NEW

Arnold O. Beckman

DISSOLVED OXYGEN ANALYZER

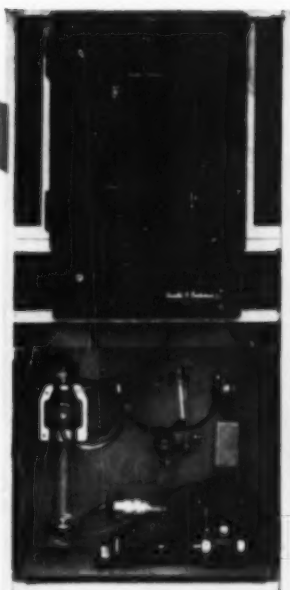
for continuous measurement!

The accurate measurement of dissolved oxygen in fluid process streams is widely recognized as an important control factor in such municipal and industrial operations as sewage and water treatment . . . waste disposal . . . petro-chemical and chemical processes . . . food processes . . . and many others.

Now, you can make such measurements—continuously, simply and accurately—with the newly-developed Arnold O. Beckman Model 1A3B Dissolved Oxygen Analyzer!

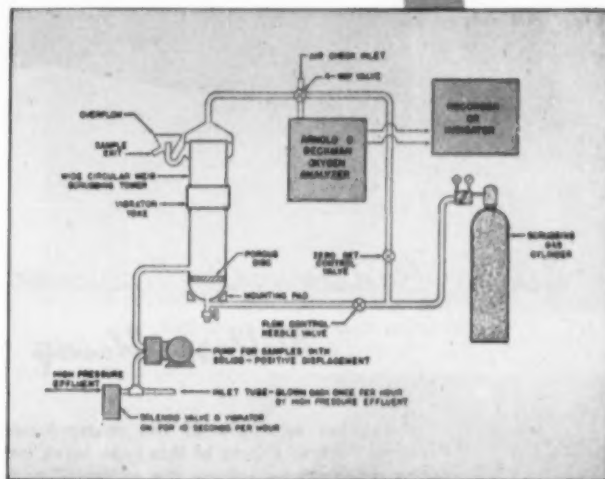
- The new Model 1A3B combines the field-proven Arnold O. Beckman paramagnetic principle of oxygen measurement with an improved method of stripping to provide a measurement specific for oxygen.
- The Model 1A3B is factory-calibrated to read in percent saturation so that efficiency of aeration or deaeration is shown directly. Or if preferred, the instrument can also be supplied to provide readings directly in parts-per-million.
- The Model 1A3B can be directly connected to any standard potentiometer-type recorder or indicator. No special accessory equipment is needed.
- Using the Model 1A3B is far superior—in speed, accuracy and convenience—to conventional chemical methods—and provides—immediately and continuously—the necessary control information for maintaining optimum processing uniformity.

With a few variations the Model 1A3B can be adapted to a wide range of application requirements . . . to handling sludges and other liquids having high concentration of solids . . . to handling samples under abnormal pressures or temperatures . . . and to other difficult sampling conditions.



The Model 1A3B is a complete, compact unit—with the Analyzer in top compartment and the scrubbing unit below.

- Continuous record
- Handles fluids, slurries, sludges, etc.
- Simple operation
- Highly accurate



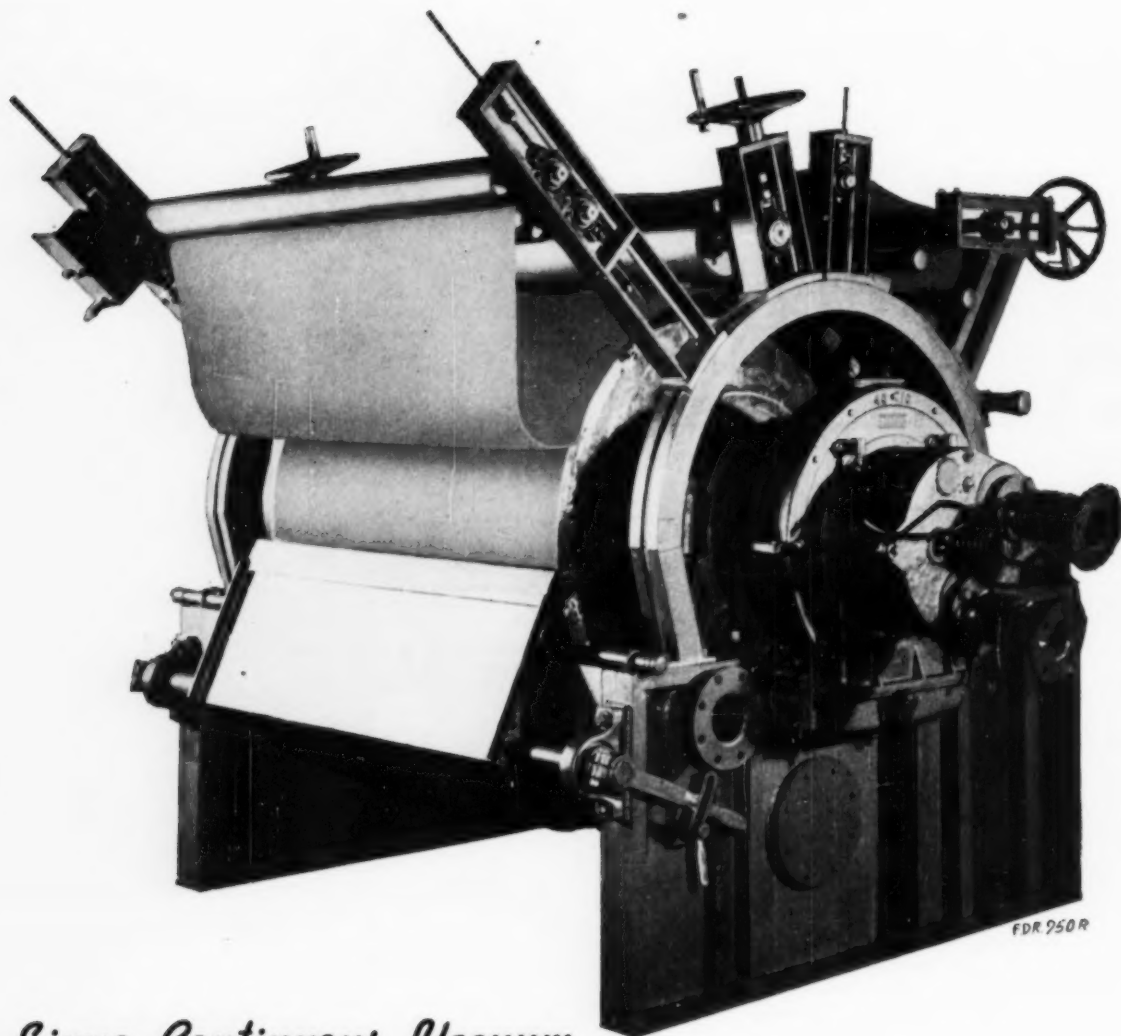
The Principle is simple and positive. The constantly-fresh test sample in scrubbing tower is stripped of dissolved oxygen by inert scrubbing gas—and result measured by Analyzer. Measurement is continuous and accurate!

RANGES—from a maximum of 0-100% O₂ saturation to a minimum of 0-5 ppm, full scale. Intermediate ranges are also available.

Arnold O. Beckman INC.

1020 MISSION STREET, SOUTH PASADENA, CALIFORNIA

Get the full story on this new Arnold O. Beckman development by writing directly for information on the Model 1A3B Dissolved Oxygen Analyzer. Ask for Data File # 13-A-124.



Eimco Continuous Vacuum Filters Using Compression Blankets

Another example of the many types of Eimco Continuous Vacuum and Pressure Filters. Filters of this type have been in use in many plants and provide many advantages where the material to be filtered produces a flocculent solid type cake.

Eimco filters of the type shown above, introduce a wash spray to the cake formation immediately after it emerges from the liquid in the tank and the compression blanket binds the cake to drum within a few inches of the slurry level. The blanket covers the cake to the blow zone above the scraper blade.

This type Eimco filter prevents cake cracking, greatly improves washing and on some types of filter cake, will reduce moisture content in the cake by 8-10%.

Write for more information.

THE EIMCO CORPORATION

Salt Lake City, Utah—U.S.A. • Export Offices: Eimco Bldg., 52 South St., New York City

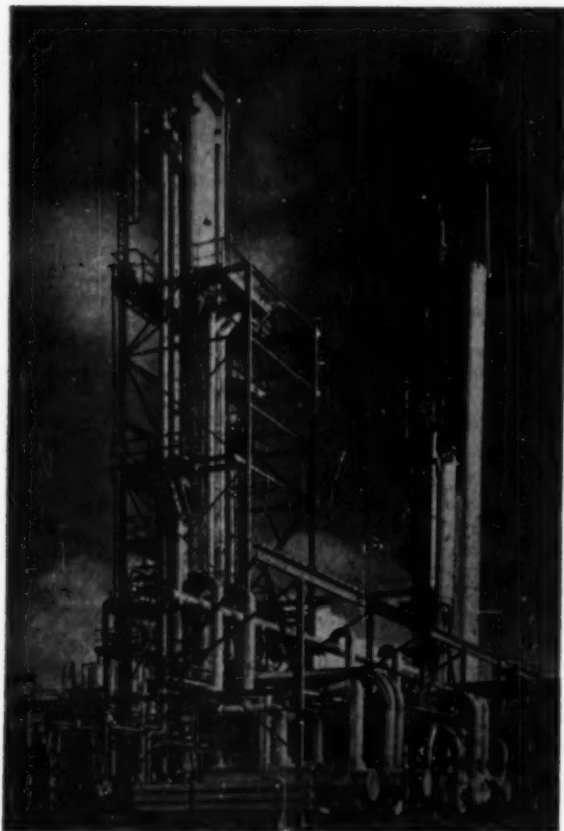
New York, N. Y. Chicago, Ill. San Francisco, Calif. El Paso, Texas Birmingham, Ala. Duluth, Minn. Kellogg, Ida. London, Eng. Paris, France Milan, Italy



You Can't Beat An Eimco!

LUMMUS

DIVERSIFIED TO BUILD OR EQUIP PETROLEUM, CHEMICAL AND POWER PLANTS



Engineering and construction of chemical and petrochemical plants



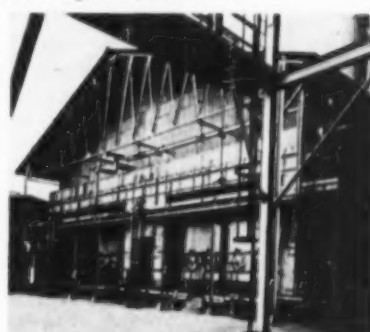
Engineering and construction of petroleum refineries



Manufacture of heat transfer equipment
(Heat Exchanger Division)



Shop fabrication and installation of pressure piping
(Fabricated Piping Division)



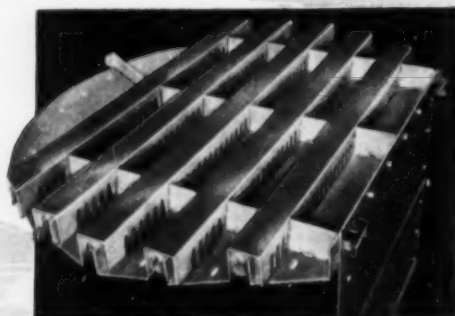
Manufacture of oil heaters
(Oil Heater Division)

In the past 50 years, Lummus has designed, engineered and constructed over 700 major plants and installations throughout the world. We would be pleased to work with you on your next project.

The Lummus Company, 385 Madison Avenue, New York 17, N. Y.
Engineering and Sales Offices: New York, Houston, Montreal, London, Paris. *Sales Offices:* Chicago, Caracas. *Heat Exchanger Plant:* Honesdale, Pa. *Fabricated Piping Plant:* East Chicago, Indiana.

Variations in BOILING PLATES AND TRAYS

... designed with a thorough knowledge of
Distillation Column Operations



Socony UNIFLUX Fractionating Tray.

We are licensed to offer
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MARGINAL NOTES

(Continued from page 22)

material, especially on equilibrium, and additional problems. Some new chapter headings are: Gaseous and Liquid Fuels, Solid Fuels, Secondary Fuels, Sulphur Compounds, Metallurgy, Ceramics, and Design Problems. Organic processes are specifically excluded.

Equilibria and heat balances are restricted to situations where the partial-pressure form of the equilibrium constant can be used and where the effect of pressure on enthalpy can be neglected. The book is not intended as a text in thermodynamics. Equilibrium diagrams for aqueous solutions and tri-axial diagrams for refractories and glasses are explained and utilized in calculations.

Much of the new material is more advanced than that of the first edition. As a result, the level of the material ranges from the most elementary application of simple chemistry and heat and material balances to quite elaborate and professionalized case treatments of complicated processes. This book is an excellent example of the intensive use of simple fundamentals carried through their applications to elaborate problems. It represents the intensive rather than the extensive method of teaching chemical engineering.

The text is largely built around solutions of many examples. Seventy-two formal numbered case problems are considered thoroughly in the text. The technique and arrangement of calculations are emphasized. More than 150 unworked problems are given. Many of these are elaborate and important in their own right. Emphasis is placed on cross-checking data for internal consistency.

This text shows every evidence of being carefully written. Its explanations are thorough and clear. It should be an eye-opener for the mature engineer who may have forgotten the power that resides in a professionalized application of simple laws to difficult problems.

Poisons in Smaller Doses

Chemical Methods in Industrial Hygiene
New York (1953), F. H. Goldman & M. B. Jacobs. Interscience Publishers, Inc., 274 pp. \$3.75.

Reviewed by Analysts, Hercules Experiment Station, Wilmington, Del.

This handy, pocket-size volume has been published as manual 3 of a series which "will provide a straight-forward description of laboratory procedures and methods." The authors are both prominent in the field of industrial hygiene analysis, hence the technical in-

(Continued on page 29)

MARGINAL NOTES

(Continued from page 28)

formation in the text is undoubtedly the best. The book deals with sampling, reagents, determination of dust sizes, inorganic compounds and gases, metals, volatile solvents, and includes a bibliography, an appendix of three good tables, and an adequate index. To cover so large a field in so small a book must have required laborious selection and rejection of material. As a result many analysts will find this book too brief and lacking adequate sampling directions; it contains no information about sources and background chemistry of the procedures nor of potential interferences of other chemicals. The book seems to be an abbreviation of Dr. Jacobs' complete and excellent treatise "The Analytical Chemistry of Industrial Poisons, Hazards, and Solvents."

This book may be useful as a laboratory text or a manual for analysts who are not interested in a broad coverage of their field.

Books Received

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Pneumatic Grain Conveying (with special reference to agricultural application). G. Segler, Institut für Landmaschinen, Braunschweig, Germany (1951), 174 pp. 18 DM.

Qualitative Inorganic Analysis. G. Charlot. John Wiley & Sons, Inc., New York (1954), 354 pp. \$7.00.

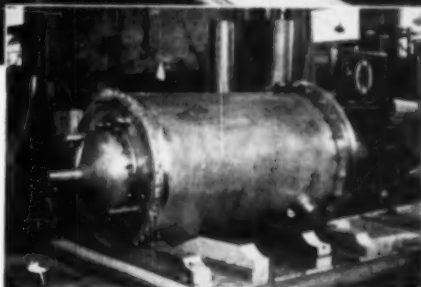
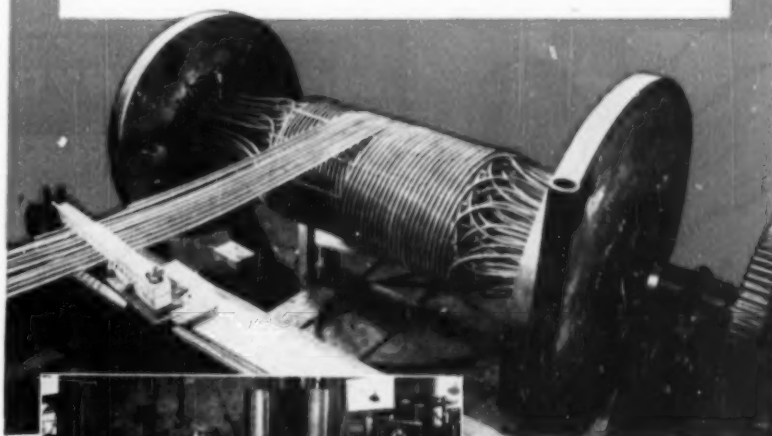
The Kinetic Basis of Molecular Biology. Frank H. Johnson, Henry Eyring, and Milton J. Polissar. John Wiley & Sons, Inc., New York (1954), 874 pp. \$15.00.

Fluid Dynamics and Heat Transfer. Engineering Research Bulletin No. 37. James G. Knudsen and Donald L. Katz. Engineering Research Institute, University of Michigan, Ann Arbor, Mich. (1954), ix + 243 p. \$3.50.

Book Listed

Phenomenes de Fluidisation. P. Reboux. Association de Fluidisation, Paris, France (1954). 165 pp. 1,800 francs.

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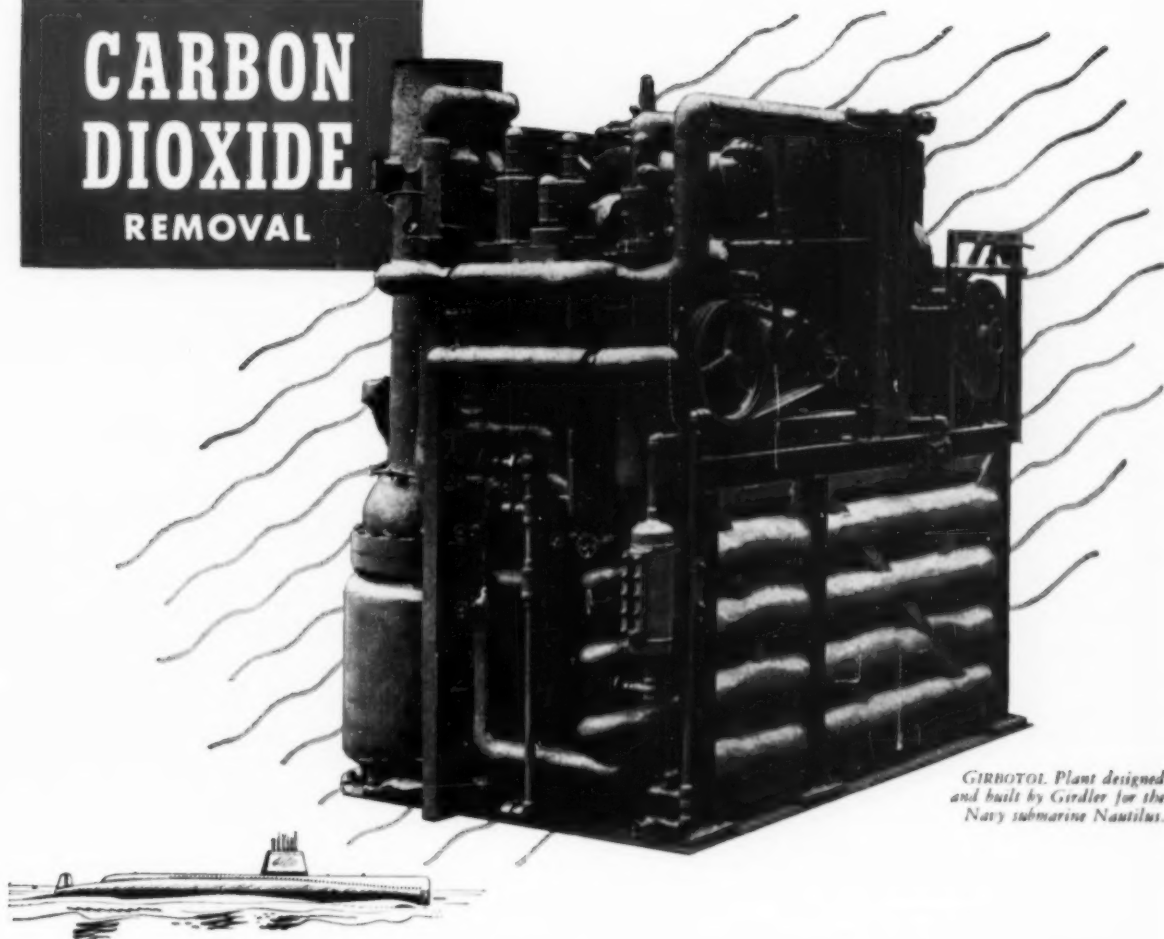
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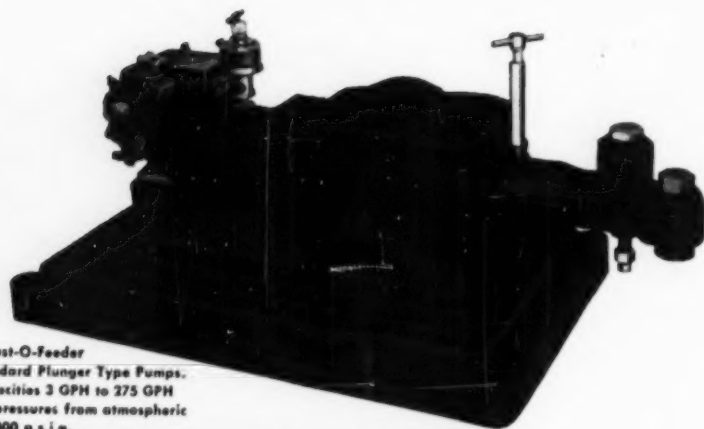
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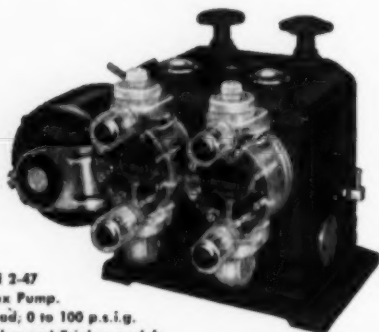
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opinion and comment

As I See It

The future of chemical engineering is a subject I have chosen to write about, on the occasion of my retiring after eighteen years as secretary of the Institute. My remarks will, on the whole, be optimistic. In this respect I have elected to differ from many of my non-chemical engineering contemporaries, by not taking a gloomy view of the future. There is a very good reason for this; I am of the belief that chemical engineering is going to provide the answers to a number of the problems and desires that a great many people worry about. This will not be accomplished, however, without overcoming problems within the profession, and I want also to discuss these.

The general outlook for chemical engineering is excellent. I base this conclusion on employment opportunities, professional status development, and the prospects for the future of the chemical process industries. In this latter connection, I cannot see any ceiling over the construction of new processing facilities. Prospects for successful commercialization of the hundreds or even thousands of untried organic chemicals, pharmaceuticals and plastics have never been better. The public is educated to expect wonders from commercial syntheses, and buys eagerly those products which add so much to our modern way of life. On the other hand improvements are constantly being made in other existing products and processes, maintaining a high rate of obsolescence of facilities for processing.

Automation in the process industries is already making its demands on the chemical engineer, who is rightfully expected to judge the over-all effectiveness of control function application, just as he is best equipped to judge any other factors affecting the technology and economics of the process plant. To keep up with advances in control devices, the chemical engineer will find it necessary to develop a close acquaintance with what can be expected from the multitude of available choices without departing from his basic role of materials processor.

The nuclear age is depending on the chemical engineer to apply his techniques to the solution

of one of the major problems in the way of economic nuclear power. This has to do with commercial scale separation of neutron-absorbing byproducts formed in fuel as it is used. To remove these, such familiar unit operations as ion exchange and solvent extraction are being used successfully in small scale, but with hideous difficulties arising from radiation hazard and corrosion ready to confront the large scale operator.

Along with having to learn much more about his technology, both applied and theoretical, the chemical engineer is being looked to for greater participation in affairs relating to government, community, and human relations. He is very much wanted in management, as well as in conducting negotiations resulting in the sale of materials, equipment and services used in processing. I take great pride in seeing the progress being made by the Institute in better serving its members' growing needs through the inclusion of a broader range of subject material in its publishing program and through the activities of its Professional Development Committee. There is every reason to believe we are at the threshold of a new era in the professional society's service to the engineer.

Of course, there aren't enough chemical engineers. To some, this may appear as conducive to personal prosperity. I believe, however, we are so far from a state of saturation, that we may discard our fears and concentrate instead on finding better ways to make use of the chemical engineers' talents. We might as members of society take serious note of the graduation rate of engineers and scientists in the Soviet Union, and ask if we have not yet reached the point where we can expect Selective Service to endeavor to better appreciate the worth of our engineers working as civilians. The conservation of our chemical engineering manpower resources might be aided by placing greater emphasis on the training of technical aides.

In closing, let me say that happiness with his position is within the province of every chemical engineer, and that it is a prime requisite to success.

STEVE TYLER

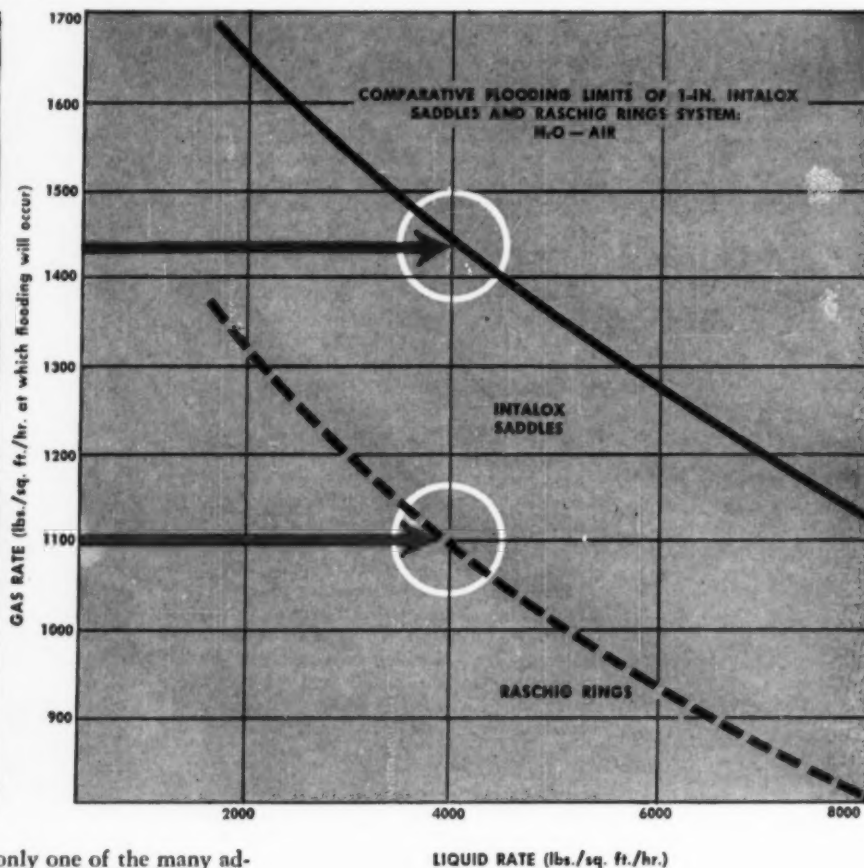
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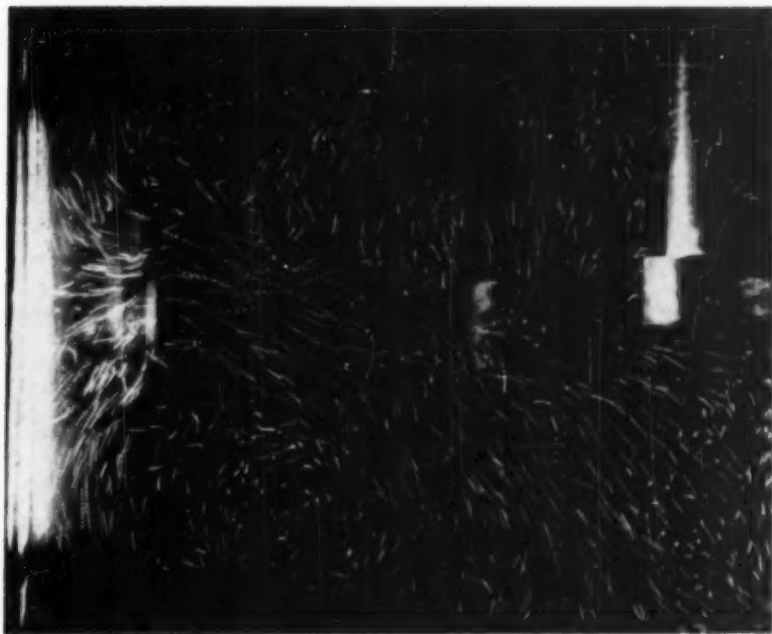
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how to make use of recent mixing developments

J. H. Rushton

Illinois Institute of Technology, Chicago

The December issue of Chemical Engineering Progress contains four articles on research pertaining to mixing. Two symposia on mixing have been held at recent Institute meetings, and many of the papers have been published either before (1) or in this issue. A large number of reviews and research papers on fluid mixing have appeared in recent years (5, 6, 9) and it is appropriate at this time to examine the trends in the investigations and to assess the practical value of our information.

Persons closely in touch with the application of mixing equipment in chemical processing think that more has been learned during the past three years than ever before about the underlying principles of fluid mixing and how to apply them. This has come about by

focusing more attention on the fluid mechanics inherent in mixing operations than on investigations aimed primarily at solving process problems for particular chemical reactions. Accordingly, much work has been done to evaluate the behavior of fluids being mixed in terms of their physical properties, and attention has been paid to the macroscopic and microscopic fluid motion patterns induced by rotating mixing impellers. The following discussion is intended to show how the recently published data on the fluid mechanical aspects of mixing are being applied to the specifications of commercial operations and to bench-scale laboratory process studies.

J. H. Rushton is also director of research for the Mixing Equipment Co., Rochester, N. Y.

Fluid Motion

The primary purpose of mixing of fluids is to distribute components rapidly in a random manner and to a homogeneous disposition. Such an accomplishment may then be followed by a chemical reaction or a transfer of matter between phases. The mixer produces only mechanical effects in the fluids involved. The discharge stream from the impeller initiates the large scale flow pattern of the entire mass of fluid; this is the macroscopic aspect of the flow motion. Turbulence, brought about by velocity discontinuities adjacent to the discharge stream and by boundary and form separation effects (9), is the microscopic aspect of the flow. Both large scale macroscopic motion (hereafter referred to as mass flow) and small scale microscopic motion (turbulence) are ordinarily required to bring about rapid mixing. Turbulence is generated by and spreads throughout the mass flow, and the mass flow then carries the turbulence to all parts of the container. Some mixing operations require relatively large mass flows for most effective mixing, whereas others require relatively large amounts of turbulence. Hence, it is of value to understand how a mixer can achieve a desired ratio of mass flow and turbulence and, further, how the optimum ratio can be determined for a particular application, whether it be for a simple blending or for affecting a chemical reaction. Much of the present day research is being directed to this end.

One important result of turbulence and its generation is that momentum is transferred from rapidly moving streams to slowly moving fluid. By this mechanism fluid is entrained by and mixed with the higher velocity flow stream. The blending of petroleum liquids by simple jets and side-entering mixing impellers is explained by entrainment, and the process has been analyzed in a recent publication (8). It is now possible to write accurate specifications for mixers to blend fluids of various physical properties at desired rates.

Turbulence is an important factor in liquid-liquid extractions. The effect of a mixer on the interfacial area of drops of one liquid dispersed in another is the subject of a paper by Vermeulen, Williams, and Langlois (in press). The interaction of mass flow, turbulence, and physical properties is a complicated one, and much more research is needed to relate the mass transfer across boundaries to the fluid mechanics induced by the mixing system.

Power—Flow—Turbulence

Fluid components will move about and diffuse of their own volition, and a

mixer is used to produce forced movement so that the components will be moved about more rapidly. Energy must be expended to cause fluid movement; it is, therefore, essential to know the power required to turn mixing impellers so that equipment size and energy costs may be determined. Further, it is possible to achieve large or small ratios of mass flow to turbulence for the same power input, depending on the size and rotational speed of the impeller. Thus, different flow motion effects can be achieved for the same power expenditure by proper sizing of impellers so that the optimum processing requirements of a particular application can be met (9).

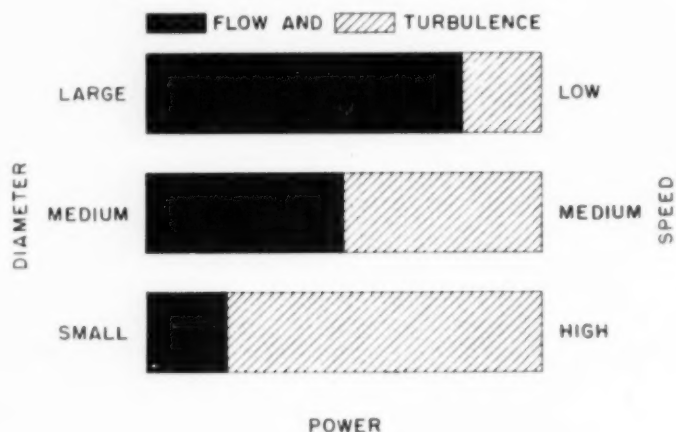
Figure 1 illustrates the differences in mass flow and turbulence which can be achieved for the same power input for

where mixing is important, the effect of the impeller diameter—turbine diameter ratio should be determined, as in Figure 2. If an optimum ratio is found, it is the basis for larger scale design.

Mixing Specifications and Control

It is apparent from these examples that a knowledge of the flow motion (the over-all pattern of flow and the quantity of mass flow and turbulence) caused by a mixing impeller is of use in sizing mixing equipment for industrial applications. It is also clear that this knowledge can form the basis for the design of bench-scale and pilot plant experiments to evaluate the optimum flow-turbulence ratio for a particular chemical or other operation. Available data on power and on flow and

Fig. 1. Constant power, effect of impeller size, and speed on



dimensionally similar impellers. A large-diameter low-speed impeller produces a large ratio of flow to turbulence, whereas a small-diameter high-speed impeller will give a small ratio. Some reactions requiring mixing are best accomplished by large flow and small turbulence. This is illustrated by curve A in Figure 2. This curve, which is typical of blending operations, shows that the rate of blending increases to a maximum with a large impeller as impeller diameter is increased (and impeller speed is decreased) with power input constant.

Curve B of Figure 2 is typical of gas-liquid contacting operations. Here the rate of mass transfer between phases increases to a maximum at small impeller diameter and then decreases as impeller diameter is increased. The significance is that more turbulence is available with the small impeller and that turbulence is more important than flow in this operation.

In all bench-scale and pilot plant work

turbulence are summarized in a recent publication (9). Additional data on discharge flow of flat-blade turbines are given in the paper by Sachs and Rushton in this issue. The experimental techniques used are valuable for both flow and turbulence studies. The use of these relations is of great practical value and gives a sound basis for evaluating the effect of mixing, for sizing large scale equipment, and for controlling mixing in bench-scale and pilot plant work while determining the effect of other process variables.

The Important Impeller Types

Since it is now well known that the ratio of flow and turbulence can be varied for equal power input by using different sized dimensionally similar impellers, there is very little incentive to experiment with a large variety of impeller shapes. The large majority of mixing operations are now performed

with marine-type propellers, flat- or curved-blade turbines, and simple flat paddles (5, 9). The choice among them is usually made on two counts: the flow pattern desired and the net cost of the mixer and its operation. When the fluid is properly baffled, or the impeller properly positioned, or the fluid viscosity sufficiently high (9) so that swirling is eliminated, there are two basic flow patterns produced by impellers. The propellers give axial flow patterns and the turbines and paddles give radial flow patterns. The relative position of the impeller to the bottom of the vessel, to the liquid surface, and to the tank wall can have surprisingly large effects on flow patterns. Motion picture studies and flash photograph studies (like the

and above) it is imperative, for mechanical reasons, that load fluctuations be held to a minimum.

Scale-Up

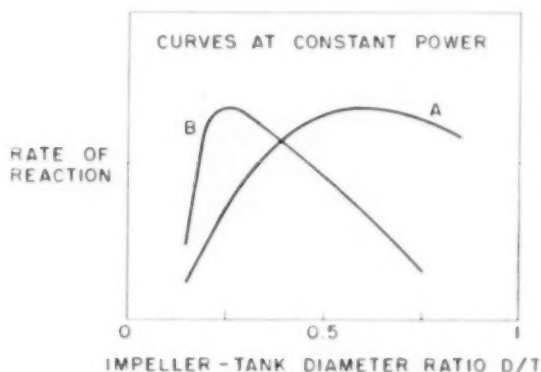
The results of bench-scale and pilot plant experimentation can be scaled-up to large equipment by correlating performance with fluid mechanics principles. Data and techniques in recent literature are useful in scaling-up heat transfer performance (2, 7), solubility (4) and other requirements (9). In this issue the paper by Oldshue and Gretton gives heat transfer data which are employed for process design specifications, and the paper of Hixson, Drew, and Knox suggests an over-all type of treatment to project small scale data on mass transfer

flow from the impeller is proportional to the speed of rotation. Therefore, it is possible to adjust the flow from the impeller by changing the speed to accommodate any flow-through rate in the system so that the desired rapid distribution of incoming flow can be made. If the inflow is directed to the center of the plate of a turbine, the distribution will be very uniform in the discharge stream. The flow rate from the turbine can be made two times, or ten times, or any other multiple of the inflow to achieve a rapid dispersion. Thus, one part can be distributed in two parts, or ten parts, or any other multiple, and so prevent significant by-passing and nonhomogeneity.

Mixing of Solids, and of Liquids with Solids

Only a few studies have been made on the mixing of solids and the mixing of small amounts of liquids with solids (10). The mixing of solids with solids is dependent on many variables, the interaction of which is often very obscure.

Fig. 2. Effect of impeller size on reaction rate at equal power input.
TWO DIFFERENT PROCESSES A AND B



photograph on the front cover of this issue) show that it is possible to obtain axial flow even with simple flat paddles (no pitch to the blades)! It has been observed that the flow from flat paddles may be radial for a time and then suddenly change to axial flow; after a time the flow will return to a radial pattern. Apparently many paddle impellers behave in this irregular way. Consequently, it is much more difficult to size paddles to perform economically as compared with turbines and propellers, where the flow can be controlled to a more uniform degree. Peculiar and unexpected effects can be found even with propellers and turbines unless they are positioned properly in the liquid. Accordingly, considerable attention has been given to the study of the three principal impeller types to understand the pattern of flow motion desired and how to reproduce it on large plant size equipment. The elimination of flow-pattern changes during mixing is important from the standpoint of steady process conditions; moreover when flow patterns change, the power demand of the impeller usually changes appreciably. In large equipment (50 hp.

operations to large scale plant installations. The paper by Overcashier, Kingsley, and Olney presented at the San Francisco meeting of A.I.Ch.E. gave data for extraction rates as a function of mixing.

Such papers show developments toward a fundamental understanding of the mechanisms of heat and material transfer. They orient ideas to the most important factors of fluid mechanics and mass transfer mechanics which apply in mixing operations. The relations between flow, turbulence, and reaction rate illustrated in Figures 1 and 2 should apply to the ideas developed in the papers just cited. The significance of papers of this type is that they are further steps in the development of methods already in use to draw up accurate specifications for large scale process equipment.

Continuous-Flow Processing

The continuous-flow systems are important commercially, and there is direct tie-in between papers published by Piret et al. (3) and the measurements of discharge flow from mixing turbines. For example, for a given impeller size the

mixing

The Weidenbaum and Bonilla paper (in press) is important in establishing clear and useful definitions which should help to orient further work in this field.

Michaels and Puzinauskas took up the difficult study of mixing a small amount of liquid with a large amount of solid. Their paper in this issue gives techniques of experimentation and of evaluation which should be of considerable future use.

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Frank Curtis

on



the first five years

Francis J. Curtis

Monsanto Chemical Company, St. Louis, Missouri

"All is not sweetness and light" would seem to be the attitude of industry with regard to engineers and the first five years. We must remember that when we speak of industry we are speaking very largely of the opinions of many who are anywhere from one half to a full generation older than the beginning engineer. As far as I can find out in history, no older generation has ever approved of a younger, and each in his turn goes through the same metamorphosis; so let us not take too disconsolately the criticisms which are always offered as to the failings of the younger generation. We can be assured that the fault is never entirely on one side; however, this is no reason at all for not working on these criticisms, if only to make certain that the new generation will grow up sufficiently well as to be able to criticize its following one in the same manner.

I should state in the beginning, since I have spent all my life in the chemical industry, the remarks I make apply only to chemical engineers. However, I am very certain that they are general enough and that the situations are sufficiently prevalent for them to apply to any group of engineers.

Fundamentally, industry expects that a college graduate will be a man not a boy. Maturity in engineering may not go along at all with maturity in character. There is surprisingly little criticism of engineering ability and training but a great deal in the field of character. The program of the training committee of E.C.P.D. represents a big forward step in solving many of these troubles but it deals, largely, with the post-graduation stage.

Previous to Graduation

In the 1953 report of E.C.P.D., page 15, there is a very pregnant sentence which shows that the committee is quite alive to this situation. It states, "It has become increasingly apparent that the time to begin to talk to the young man about professional development, is not after graduation." With this observation, I am thoroughly in sympathy. Chemical engineering was invented by design engineers, is taught by design engineers, and for design engineers. The trouble has been that too good a job was done in making them. We in industry have pushed these chemical engineers into many fields for which they were not specifically trained. We have put them in chemical research, in which those who take to it do surprisingly well, and in production, sales, commercial development, business research, and management. I must take my full share of responsibility for this development. When I first went into production in the early twenties the men in charge, at least in our plant, were not technical. This was changed rapidly. Likewise, when I went into sales, in the beginning I was the only technical man in the whole sales department. This also has been changed rapidly. I now begin to wonder whether we were right.

The training which the engineer obtained in college did not and does not specifically fit him for these activities. The reason behind this expansion was the belief that engineering is excellent mental training for anything. I have always been impressed by the fact that a lawyer will take on any kind of a job, legal or not, because he knows his legal

mental training will back him up. I believed and still believe that as far as mental training is concerned, the same is true of engineers. However, I have now come to think that in a great many cases they do not have this point of view themselves.

It may be interesting to see the breakdown of chemical engineers in Monsanto.

DISTRIBUTION OF ENGINEERS

	%
Commercial development	2.5
Administration	3.5
Sales	9.9
Research	19.1
Engineering	21.0
Production	44.0

Many engineers left college, and many still leave college, without any conception of this. They thought that life was to be the designing of columns and the figuring of heat transfer. Many were shocked to hear that there is such a thing as shift work in life. A very recent survey at one of our production plants shows that 33% of the members of supervision, practically all chemical engineers, think that their training and ability is not being sufficiently utilized. I do not worry about the criticism on ability because very few people think that their real ability is recognized, but I am upset by the fact that so many engineers feel they are not using their training. As a matter of fact, if they would only look upon their training as general rather than particular, they would see that their habits of analyzing problems, weighing evidence, putting together conclusions developed through the study of chemical engineering are used every day of their lives.

It would be my recommendation to the training committee not to take my word on this situation but to make a careful study with a number of companies and develop a program based on the results.

Decision on the Job

I feel that man's job is very important to him. I realize that there is quite a school of thought which advocates a good deal of shifting around but it is a school with which I cannot find myself in agreement. Starting to work in industry is difficult enough anyway for a man who has spent his life in school. If he gets off on the wrong foot, it may take years to recover and he may never get over the effect of an initial failure on himself and on future employers. I have been appalled at the reasons given for many decisions on the first job. Quite a few are based on an additional five dollars a month, which is the most picayune reason I can think of. Many are concerned with location; they don't want to leave the West Coast or Texas, they want to be near Cape Cod or Long Island for sailing, or they may want to be in a big city or in a little town. Apparently, almost any motivation is bigger than the opportunities of the job.

Such thinking is not really a matter of engineering training but of character and of sense of values. I do not know whether the fault is in the home, in the schools, or in the general atmosphere of the time, but if a man twenty-one years of age is controlled by motivations such as these, he is a boy, not a man.

Industrial Training

Above all, I do not wish to leave the impression that all of the fault is in the home or college. Until almost yesterday most industries used the "sink or swim" method as a means of sorting out those who were to succeed and those who were not. Fortunately, in the last ten years this attitude has greatly changed and most companies now recognize their obligations. Those who are doing nothing about them are getting very rare. The whole field of industrial training is in more of a flux than is academic education. If you analyze chemical engineering courses in one standard university, you will find that they are equivalent and similar to those in another. This is not true in industrial companies.

Based on the "man not boy" concept, we do not favor in-plant classes even when conducted by the famous case method. We feel by this time the man must begin to learn judgment

by holding a job and learning from his failures. Of course, he may regard a low mark as a failure but it is not quite the same thing as one which involves a loss to the company about which he hears plenty or one which at long last affects his own pay check. I do not think there is any substitute for actual doing when a man reaches the point where our young engineer out of school and on the job is. On-the-job coaching is supplemented by management development conferences on various facets of the business. These necessarily vary depending upon the field in which the man is working. The kind we favor most is the so-called slanting type, where all levels of supervision, from foreman up to plant manager, take part but no man sits in the same group with his own superior. Obviously, this is practical only in large plants. Departmental meetings also take place but they are more for specific technical matters than management training.

The key point of the whole system is the appraisal interview whereby each man sits down with his immediate superior at least once a year and goes over with him a performance review in which they discuss his activities in the various facets of his job, talk over where he has done well and where he has done poorly, and lay out a plan for his future development to correct the defects brought out. An important point in this whole system is that it must be carried out by the line organization and not by a staff department. The latter can be of invaluable assistance in giving information in training and techniques and in contributing the inspiration to keep the system going, particularly by persuading the older members of the line organization that helping younger men in this way is not mollycoddling.

However, no progress can be made by the best training system in the world unless the men being trained are motivated by desire for self-development. I was very glad to see the emphasis put on this factor by the report of the training committee. As long as they hang back, we can get nowhere and I don't care how much money is spent on training courses, consultants, or anything else.

We believe also in out-of-plant schooling and one of our divisions has a partial assistance program. I do not feel that companies should pay all the expenses of outside school training since it is a well known fact that no one appreciates anything that is free. I should like to point out, however, that policies of this kind are quite difficult for multiple plant companies since it may well be that there are many locations which are not fortunately situated with respect to universities and, therefore, some

plants get to be favored more than others. Rightly or wrongly, this is the problem to be faced.

What Do We Expect?

We expect therefore that a man should study carefully the openings which become available to him and realize that he is no longer in school. If he wants to use only his school training, he should stick to the jobs that do use it and not chase after those which offer more money but may require ninety per cent of his attention on costs, human relations, and getting out or disposing of the goods. He should cooperate and work hard on all the programs put forth to improve him and help to improve these programs by judicious criticism. He should realize that when he came from school he was only an embryo not a finished product and that what he does not know is much greater than what he does. He should recognize that his chemical engineering has trained his mind to analyze problems, to form clear conclusions, and to act, and is, therefore, of value in any business which he may undertake although it may be far from engineering per se.

Have We Pushed the Engineer Too Far?

I pointed out earlier the distribution of chemical engineers in one company and I am sure that an analysis of almost

professional development

any chemical company would show somewhat similar figures. It is quite true that in most of these jobs design engineering plays little or no part. Have we, therefore, made a mistake and pushed the engineer too far? Some of us are beginning to think so. This year we expect to start again hiring liberal arts candidates for sales. Whether we will go further, I cannot as yet say but I think that we will do some experimenting. At least it would not take too much of a move in this direction to solve the problem of the shortage of engineers.

What About the Future?

If the engineer is to hold the place he has made for himself, the schools must recognize that their production line can no longer be a single one. In this I feel that the training committee of E.C.P.D. can be of great help.

Presented at the meeting of the Engineers' Council for Professional Development, Cincinnati, Ohio, October 29, 1954.

the time of a transfer unit and an agitation number for batch operations involving mass transfer

A. W. Hixson, T. B. Drew, and K. L. Knox

Equations for mass transfer between two phases in an agitated system have been developed to obtain an expression for the time of a transfer unit. For mass transfer in steady-state operations, the time of a transfer unit multiplied by a velocity term was equal to the height of a transfer unit. For mass transfer in agitated batch operations, the time of a transfer unit was multiplied by a suitable velocity term to yield an agitation number which was nearly constant over a limited range of agitation conditions and equipment sizes for dimensionally similar systems with the same physical properties. The equations were illustrated with previously published data on mass transfer in agitated systems.

Chilton and Colburn (2) have developed equations leading to the concept of the height of a transfer unit for systems operating in a steady state. This concept has found a wide application in diffusional processes, particularly those of distillation and absorption.

Many batch operations involving mass transfer between different phases are also diffusional processes. For these systems the differential rates of mass transfer can be integrated with respect to time to yield a new unit called the time of a transfer unit. The time of a transfer unit is equal to $1/F_1 a_m$ where F is a mass-transfer coefficient and a_m is the interfacial surface area per mole. Hixson and Baum (6) found that the mass-transfer coefficients in a dimensionally similar series of vessels stirred with a propeller were proportional to the first power of the product of the vessel diameter and the propeller speed. In such a case the time of a transfer unit may be multiplied by the product

of the vessel diameter and propeller speed to yield the agitation number, which is nearly constant over a range of vessel diameters and propeller speeds for a dimensionally similar system. The agitation number for batch operations is analogous to the height of a transfer unit for steady-state operations.

In terms of the film theory of mass transfer between two phases as formulated by Colburn and Drew (3, 4), the total molal rate of increase of phase 1 is

$$\frac{dW_1}{d\theta} = F_1 A \ln \left(\frac{Z_{1a} - Y_{1a}}{Z_{1a} - Y_{1a}} \right) \quad (1)$$

where

W_1 = total number of moles in phase 1

θ = time

F_1 = film mass-transfer coefficient

A = area of interphase contact

Z_{1a} = fraction of flow $dW_1/d\theta$ across the interface which is substance a

Y_{1a}, Y_{1a} = mole fractions of a in phase 1 in the body of the phase and at the interface respectively.

The molal rate of increase of substance a in phase 1 is, from the definition of Z_{1a} and Y_{1a} , given either by $Z_{1a}(dW_1/d\theta)$ or by $dY_{1a}W_1/d\theta$. Equating the first of these expressions to the expanded form of the second and solving for $dW_1/d\theta$ gives

$$\frac{dW_1}{d\theta} = \frac{W_1 dY_{1a}}{(Z_{1a} - Y_{1a}) d\theta} \quad (2)$$

which, if used to eliminate $dW_1/d\theta$ in Equation (1), results after rearrangement in

$$\frac{dY_{1a}}{(Z_{1a} - Y_{1a}) \ln \left(\frac{Z_{1a} - Y_{1a}}{Z_{1a} - Y_{1a}} \right)} = \frac{d\theta}{(W_1/F_1 A)} \quad (3)$$

When there is equimolar countertransport across the interface, Equation (3) becomes

$$\frac{dY_{1a}}{Y_{1a} - Y_{1s}} = \frac{d\theta}{(W_1/F_1A)} \quad (4)$$

The left side of either Equation (3) or (4) is the differential number of transfer units dN required to effect the differential increment in mole fraction dY_{1a} . In the usual applications in the literature the change is that accomplished as a stream of phase 1 flows through a height dH in a steady-flow contacting apparatus; the strictly analogous derivation for the case (5) leads, instead of to the expression here appearing on the right of Equation (3), to $dH/(G_m/F_1a)$ where G_m is the superficial molal mass velocity of phase 1 and a is the interfacial area of contact per unit volume of apparatus. Following Chilton and Colburn (2) this expression (G_m/F_1a) has been called the height of the film transfer unit for phase 1. In the present case dY_{1a} is the change accom-

plished during time $d\theta$ in the composition of a quantity of phase 1 resident, say, in a tank. By analogy with the height of a transfer unit the quantity on the right of Equation (3) may be called the time of a transfer unit

$$(T.T.U.)_1 = \frac{W_1}{F_1A} = \frac{1}{F_1a_{m1}} \quad (5)$$

where a_{m1} is the interfacial surface area per mole of phase 1.

The derivation of over-all time of transfer units is analogous to that of over-all heights of transfer units and the relations among the several heights of transfer units go over readily into corresponding times of transfer units.

An agitation number (N_A) may be defined as the product of the time of a transfer unit and a velocity term for the agitation system. If the mass-transfer coefficient varies as the first power of the velocity term selected, the agitation number would be constant for a given ratio of area to total number of moles. Such an agitation number for a batch

operation would be analogous to the height of a transfer unit for steady-state operation and such an agitation number would be a measure of the effectiveness of agitation in a batch system in the same way that the height of a transfer unit is a measure of the effectiveness of continuous contacting equipment.

The agitation number would have the same advantages and disadvantages that are associated with the height of a transfer unit. An advantage would lie in the constancy of the value of the agitation number over a range of agitation conditions. A disadvantage would lie in the dependence of the agitation number upon the ratio of the surface area to total moles of phase, upon the shape factors associated with the system and upon the physical properties of the system.

Applications to Experimental Data

Experimental data have been taken from the work of Hixson and Crowell (7), from Hixson and Baum (6) and from Mack and Marriner (8) to illustrate applications of the time of a transfer unit and the agitation number.

Hixson and Crowell gave data for the

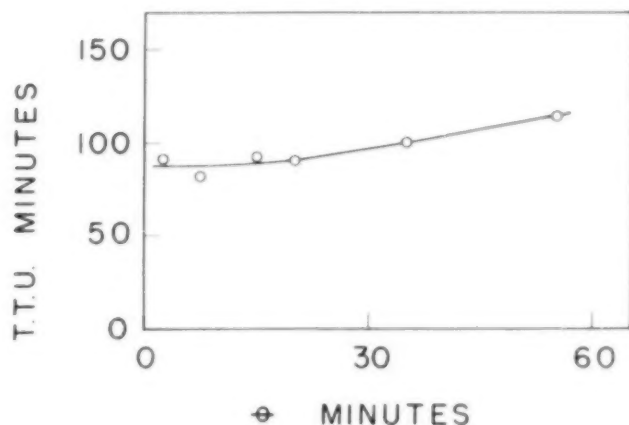


Fig. 1. Times of transfer units for the dissolution of naphthalene in ethyl alcohol.

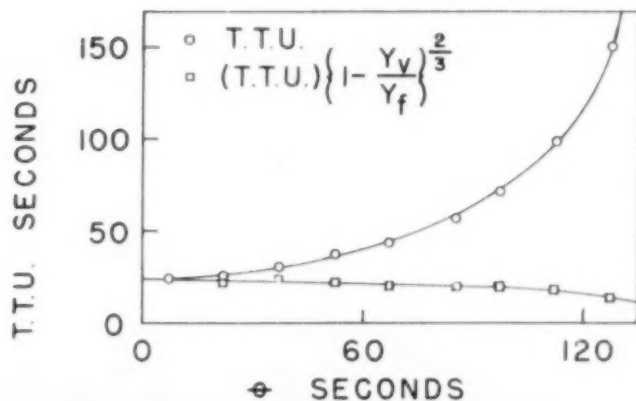


Fig. 2. Times of transfer units for the complete dissolution of common salt in water.

mixing

rate of solution of a single ball of naphthalene in ethyl alcohol when the alcohol was stirred with a single-paddle glass agitator rotating at 150 rev./min. The mole fraction of naphthalene in the ethyl alcohol was designated as Y and the mole fraction in a saturated solution was designated as Y^* . Since Y^* was a constant for the temperature of the ex-

Table 1.—Times of Transfer Units for the Dissolution of Naphthalene in Ethyl Alcohol Based on Data from Hixson and Crowell (7), Table 1, Experiment III

θ min.	Y	Y^*	ΔN	T.T.U. min.
0	0	.02355	.0543	92.1
5	.001241	.02355	.0615	81.3
10	.002783	.02355	.1072	93.3
20	.004888	.02355	.1097	91.2
30	.006828	.02355	.150	100
45	.009156	.02355	.178	113
65	.011150	.02355		
Avg. value				95.3

periment, since all values of Y were small compared to 1, and since $Z = 1$ for this case, a simplification of the expression for the time of a transfer unit was possible.

$$\Delta N = \int_{Y_1}^{Y_2} \frac{dY}{(Z-Y) \ln \left(\frac{Z-Y}{Z-Y^*} \right)}$$

$$= \ln \left(\frac{Y^* - Y_1}{Y^* - Y_2} \right) = \frac{\Delta \theta}{T.T.U.} \quad (6)$$

Data, treated in accordance with Equation (6), are shown in Table 1 and in Figure 1. The time of a transfer unit was nearly constant for times of less than 20 min. The high value of the time of the transfer unit indicated that the naphthalene was dissolving slowly. The increase in value of the time of a transfer unit at higher times was probably due to a decrease in the surface area as the sample dissolved.

In another experiment Hixson and Crowell completely dissolved common salt in water, using 2 kg. of water at 20° C. and agitating the system with a 4.25-in. by 1-in. paddle agitator at 241 rev./min. In this case the time of a transfer unit changed significantly as the salt dissolved. This change was partially explained by applying the cube root law of Hixson and Crowell to correct the time of a transfer unit for the change in area of the crystals. This corrected value of the time of a transfer unit is shown in Table 2 and in Figure 2 as $(T.T.U.) (1 - Y_e/Y_f)^{2/3}$ where Y_f represents the mole fraction of the completely dissolved salt. Values of the time of a transfer unit corrected according to the cube root law became somewhat smaller with increasing time and this may have been due to some attrition of the crystals as they dissolved.

In liquid-liquid or liquid-gas systems the intensity of agitation affects both the interfacial area and the mass-transfer coefficients. Though the time of a transfer unit has been used as a measure of performance in liquid-liquid systems (1), the effect of agitation on the degree of dispersion and on the mass-transfer coefficient was not separated.

Hixson and Baum (6) studied the rate of solution of rock salt in water, using a series of dimensionally similar vessels and propellers. Results from their original data are shown in Table 3, and Figure 3 illustrates some agitation numbers. The agitation number for this case was defined as the product of the time of a transfer unit, the propeller speed, and the vessel diameter. The results show a tendency for the agitation number to increase with the propeller velocity in the same way that the height of a transfer unit increases slightly with increasing linear velocity through a tower.

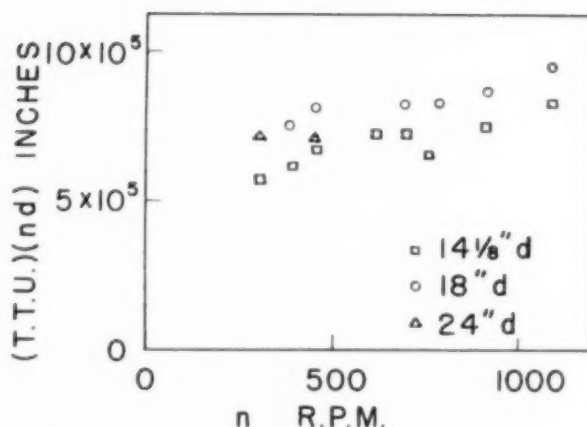


Fig. 3. Agitation numbers for the dissolution of rock salt in water.

Table 2.—Times of Transfer Units for the Complete Dissolution of Common Salt in Water Based on the Data of Hixson and Crowell (7), Table 6, Experiment 53

θ sec.	Y_e	Y^*	ΔN	$T.T.U. (T.T.U.) \left(1 - \frac{Y_e}{Y_f}\right)^{2/3}$	
				min.	min.
0	0	.1101	0.0110	22.7	22.7
15	.00120	.1101	0.0105	23.8	20.5
30	.00233	.1101	0.00832	30.0	21.5
45	.00322	.1101	0.00707	35.4	20.9
60	.00397	.1101	0.00702	40.3	19.1
77	.00471	.1101	0.00450	48.2	16.5
90	.00514	.1101	0.00363	68.9	17.4
105	.00552	.1101	0.00268	93.3	17.3
120	.00580	.1101	0.00182	137	13.8
135	.00599	.1101		Avg.	18.8

Table 3.—Agitation Numbers and Times of Transfer Units for Dissolution of Rock Salt in Water Based on Data of Hixson and Baum (6)

Run	n rev./min.	d in.	Y_{12}^*	Y_{12e}	θ min.	$(T.T.U.)_m$	
						min.	Agitation number (T.T.U.)(nd) in.
260a	764	14.125	.0998	.001283	0.75	61.3	6.63×10^5
261	916	14.125	.0998	.001341	0.75	58.6	7.63×10^5
262	1082	14.125	.0998	.001448	0.75	54.3	8.33×10^5
263	304	14.125	.0998	.000785	1.0	134	5.75×10^5
264	382	14.125	.0998	.000933	1.0	113	6.07×10^5
265	485	14.125	.0998	.001013	1.0	103	6.70×10^5
266	620	14.125	.0998	.001258	1.0	83.5	7.33×10^5
267	690	14.125	.0998	.001402	1.0	74.9	7.30×10^5
269	382	18.0	.0998	.000945	1.0	111	7.65×10^5
270	458	18.0	.0998	.001058	1.0	99.5	8.20×10^5
272	690	18.0	.0998	.001182	0.75	66.5	8.29×10^5
273	773	18.0	.0998	.001320	0.75	59.6	8.30×10^5
274	916	18.0	.0998	.001010	0.50	52.0	8.56×10^5
275	1082	18.0	.0998	.001085	0.50	48.4	9.45×10^5
276	304	24.0	.0998	.001060	1.0	99.2	7.25×10^5
277	458	24.0	.0998	.001650	1.0	63.8	7.01×10^5
						Avg.	7.53×10^5

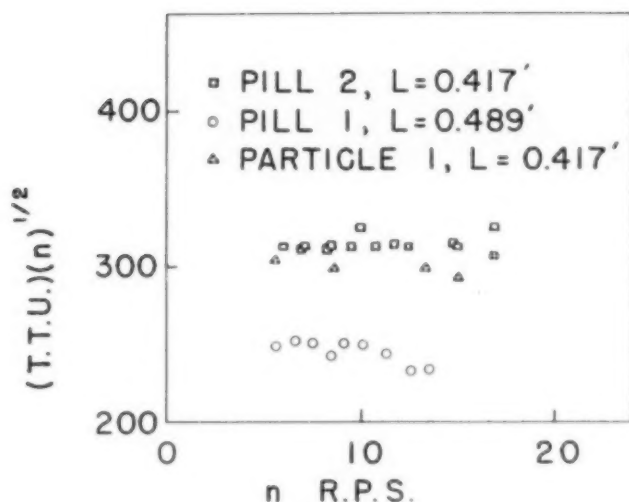


Fig. 4. Agitation numbers for the dissolution of benzoic acid in dilute sodium hydroxide.

Table 4.—Agitation Numbers and Times of Transfer Units for the Dissolution of Benzoic Acid in Dilute Sodium Hydroxide Based on Data in Table 10 of Mack and Marriner (8)

Run	n rev./sec.	L Impeller length ft.	Solid material	T.T.U. min.	(T.T.U.) (n ^{1/2})
1	8.5	0.417	Pill No. 2	104	303
2	15.0	0.417	Pill No. 2	77.0	298
3	11.7	0.417	Pill No. 2	89.2	305
4	7.1	0.417	Pill No. 2	114	303
5	10.0	0.417	Pill No. 2	98.6	312
6	6.2	0.417	Pill No. 2	121	301
7	10.0	0.417	Pill No. 2	97.6	308
8	7.0	0.417	Pill No. 2	114	301
9	10.8	0.417	Pill No. 2	91.4	300
10	8.3	0.417	Pill No. 2	104	300
11	12.5	0.417	Pill No. 2	84.8	300
12	9.5	0.417	Pill No. 2	97.6	300
13	14.8	0.417	Pill No. 2	78.7	303
14	16.7	0.417	Pill No. 2	72.3	296
15	16.7	0.417	Pill No. 2	76.4	313
				Avg.	303
1	7.6	0.489	Pill No. 1	88.3	244
2	5.8	0.489	Pill No. 1	99.7	240
3	9.1	0.489	Pill No. 1	80.4	243
4	8.4	0.489	Pill No. 1	80.7	234
5	10.1	0.489	Pill No. 1	75.5	240
6	6.7	0.489	Pill No. 1	94.6	245
7	11.4	0.489	Pill No. 1	69.3	234
8	13.5	0.489	Pill No. 1	60.9	224
9	12.7	0.489	Pill No. 1	62.3	222
				Avg.	236
1	15.0	0.417	Particle No. 1	73.4	285
2	8.7	0.417	Particle No. 1	98.6	291
3	13.3	0.417	Particle No. 1	79.3	289
4	5.8	0.417	Particle No. 1	123	296
				Avg.	290

In more recent work Mack and Marriner (8) dissolved a constant amount (12.6 g.) of benzoic acid in about 5400 g. of 0.0019 *N* NaOH solution, using particles of varying size but with a constant surface area. The time required to reach a phenolphthalein end point was observed. If one assumed that the mass transfer was limited by the benzoate ion, then

$$N = \ln \left(\frac{y^* - y_1}{y^* - y_2} \right) = \ln \left(\frac{0.000400}{0.000400 - 0.0000342} \right) = 0.0894$$

$$= \frac{\theta}{T.T.U.}$$

for these tests. For a series of tests with a baffled tank of a given diameter and liquid depth, the agitation number was defined as the product of the time of the transfer unit and the square root of the impeller speed. Data from the work of Mack and Marriner are shown in Table 4 and are plotted in Figure 4. In this case the agitation number did not vary much with the square root of the impeller speed. Different values of the agitation number were obtained with different impeller lengths and different particle sizes.

mixing

Comment

Results presented here illustrate the usefulness of the concept of the time of a transfer unit as a measure of mass transfer performance in a batch operation. Table 1 showed that the time of a transfer unit was nearly constant when the conditions of agitation were constant and when the ratio of total moles to interfacial area did not change much during the experiment. Table 2 illustrated the case of complete dissolution of one phase in another and the effect of variations in interfacial area on the time of a transfer unit.

The agitation numbers shown in Tables 3 and 4 were only approximately constant since the time of a transfer unit was not ordinarily a simple function of agitator speed and vessel size over wide limits. In this respect, the agitation number for batch operation suffers the same limitation that the height of a transfer unit does for steady-state operation.

Notation

A	= area of surface across which mass is transferred
D	= diffusivity constant in units of moles/time \times length
d	= prefix indicative derivative
d	= vessel diameter, in.
F	= mass-transfer coefficient, lb. moles/(hr.)(sq.ft.)
$H.T.U.$	= height of a transfer unit
L	= impeller diameter, ft.
N	= number of transfer units
N_A	= agitation number
n	= agitator speed, revolutions/time
$T.T.U.$	= time of a transfer unit
V	= average linear velocity of a phase, ft./sec.
W	= total moles in a phase
X	= distance
Y	= mole fraction

Z = fraction of the flow across an interface
 θ = time

SUPERSCRIPTS

* on an equilibrium value of mole fraction in one phase corresponding to the bulk concentration in the second phase

SUBSCRIPTS

a = component a
 b = component b
 i = conditions at the interface of the two phases
 f = conditions after complete solution of one phase
 o = over-all values
 v = conditions in the bulk of a phase
 1 = phase 1
 2 = phase 2

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sulfur-gas thermodynamics

E. R. McCartney

Altadena, California

A rebuttal of a technical note by B. W. Gamson appearing in the October issue on page 515.

To avoid the danger of misquotation, I supplied Dr. Gamson with drafts of my article (4) before publication. As he raised no objection on the score of misquotation in his acknowledgment of the final draft, I assumed that this contained an acceptable paraphrase of his remarks.

The original issue has been stated clearly enough by Dr. Gamson: "One common attempt . . . is predicated upon treating the complex sulfur equilibria as a single specie . . ." [sic] (2). It is worth repeating that the only experimental data on sulfur gas consists of P.V.T. measurements on the total gas. In practice, one is never concerned with individual species, and no amount of dissection and reassembly will ever yield any more thermodynamic information than already exists in the observed overall P.V.T. In fact, this course introduces avoidable errors.

When heat quantities (heats of transition between species, for example) are derived from P.V.T. data, experimental errors in the observed P.V.T. are exaggerated merely by the mathematics. When these heat quantities, in turn, are converted into free-energy expressions, the errors are further magnified by the same reason. In the present instance the situation is aggravated by simplifying assumptions. Admittedly in order to make their mathematics at all tractable, Preuner and Schupp (5) as well as Braune *et al.* (1) assumed the heats of

transition between species to be independent of temperature, contrary to usual behavior. Kelley (3), moreover, arbitrarily assumed the ΔC_p 's between species to be constant, simply because of the unlikelihood of ever being able to isolate these species and measure their properties. When the results are used merely for extrapolating P.V.T. data, these simplifications are not too serious, although systematic deviations still exist even in Braune's more careful work. However, when a reaction equilibrium constant is built upon such assumptions, it can hardly be better than order of magnitude, and such curious effects as conversions "higher than theoretical"—to quote Dr. Gamson (2)—are only to be expected. This is not too much conversion; it is too little theory.

It is less precarious, or so it seems to me, to extrapolate the P.V.T. data as such as far as operating conditions (not to perfect-gas conditions) by whatever means may seem suitable and then to minimize the effect of P.V.T. error in using the results in an expression for K . The resulting K can then be used, as stated (4), to correlate experimental equilibria. In this way all questions of species, free energies, and so on, can be ignored and the results firmly anchored to observation. Dr. Gamson missed the point of my mathematics, which was designed merely to relieve his discomfort about such a maneuver.

Dr. Gamson emphasizes, in defending his viewpoint, that the species obey the ideal-gas law, although he did not say

how he observed this. It is not very surprising, however, that the postulated species behave in the postulated manner, since the whole analysis was framed upon this requirement. The resulting ideal-gas behavior of the species is not a discovery about sulfur molecules; it is only a tribute to mathematical patience. If one really wished to obtain species, a disconcertingly prolific derivation has been described (6) by which a whole menagerie of species could be evoked, not only for sulfur but for any other gas as well. But it was not claimed that any more thermodynamic information would emerge than could be had by conventional treatment of the equation of state.

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Gamson was asked for a final comment on the above. He believes McCartney does not show use of P.V.T. data for sulfur gas without referring to derived functions based on several molecular species and that McCartney's calculations were based on concept of species.—Editor.

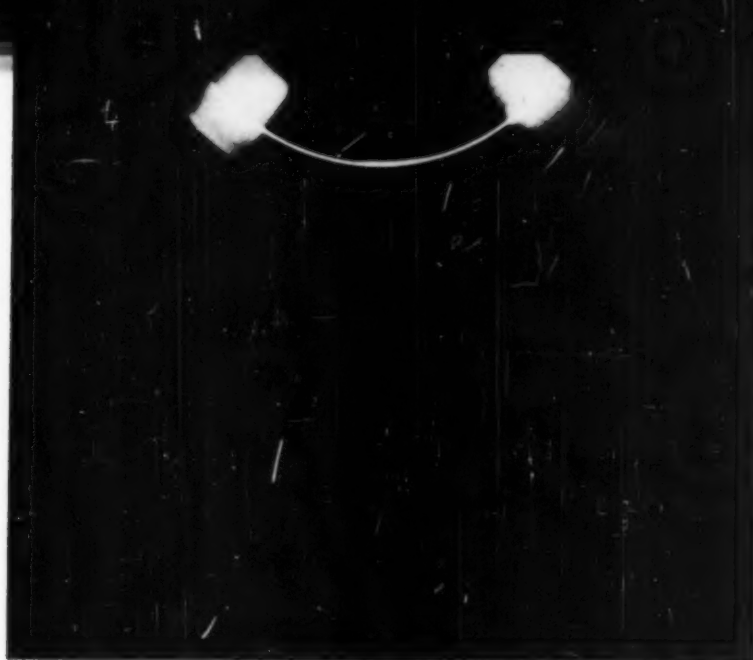


Fig. 3. Horizontal-plane trace photograph.

discharge flow from turbine-type mixing impellers

A study was made of the volumetric discharge of a flat-blade turbine operating in a cylindrical tank with baffles under conditions frequently used in liquid-mixing operations. The flow-velocity distribution was determined in the discharge stream of the impeller.

The experimental method consisted of photographing small liquid tracer droplets moving in the liquid. By means of a slit of light, illumination was restricted to a planar section in the tank, so that only the tracer droplets moving in this section were illuminated and photographed. Proper choice of camera-shutter speed resulted in the appearance of photographed tracer droplets as streaks. From the time of exposure and length of streak, it was possible to calculate the velocity of the drop.

Data are given for the radial volumetric flow through various cylindrical surfaces bounded by horizontal planes extending through the top and bottom of the turbine blades. The flow was found to be proportional to the turbine speed at various radial distances from the impeller. Furthermore, the results showed that a large amount of fluid was entrained by the discharge stream as it flowed away from the turbine.

Some of the important factors in predicting mixer performance in commercial equipment of the rotating-impeller type are flow pattern, power consumption, total volumetric-flow discharge of impellers, fluid velocities, and turbulence.

The general flow patterns in various mixing systems have been established (5). Selection of impellers for some applications is based on an advantageous flow pattern, for most applications a flow pattern producing lateral and vertical flow currents without liquid swirl being desired. Power-consumption data are available for various types of impellers which produce these flow patterns.

Some data have been published (4) on the actual discharge flow of impellers, but more are needed. In liquid-liquid

blending and other operations, the rate of mixing can be related to the liquid discharged and entrained in the moving stream.

Information on fluid velocities and turbulence is valuable for applying mixing equipment to operations involving solid suspensions, liquid-liquid extraction, and similar operations, but few accurate data on liquid velocities or turbulence in mixing vessels have been published to date.

A method is here described by which volumetric flows and fluid velocities can

*J. P. Sachs
and J. H. Rushton*

Illinois Institute of Technology,
Chicago

J. H. Rushton is also Director of Research for the Mixing Equipment Company, Rochester, New York; J. P. Sachs is at present with the Visking Corporation, Chicago, Illinois.

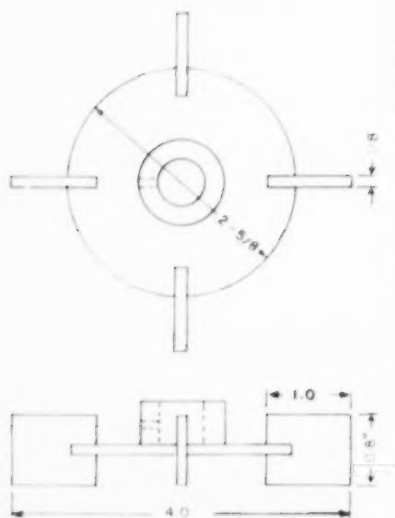


Fig. 2. Flat-blade turbine.

be determined at various points in the discharge stream of a mixing impeller operating in water with baffles to prevent swirling.

Photographic Method for Velocity Determinations

A sheet of light approximately 3/16 in. thick and 5 in. wide was used to illuminate any desired vertical or horizontal section of water contained in a glass mixing tank. A small amount of an immiscible liquid in the water was broken into small drops by the turbulence of the mixing water, and these drops were illuminated as they moved in the lighted section. Photographed the drops appeared as streaks, the lengths of which were measured, and these, together with the time of exposure, allowed the calculation of velocity. The method is similar to one used previously for the determination of turbulence in liquid expanding in pipes of changing cross section (2). The calculated velocity was assumed to equal the velocity of the surrounding fluid since the drop was very small and had nearly, if not exactly, the same density as the surrounding fluid. Illuminating various horizontal and vertical planes gave data for the radial, tangential, and vertical velocity components at many points in the tank.

Description of Experimental Equipment

Figure 1 shows the arrangement of the essential parts of the equipment. The motor drive is at the top, and the mixer shaft extends down into the cylindrical tank, which is only partially visible in the square-shaped glass aquarium. The picture shows one side covered by cardboard

containing a horizontal slit. To the left is the arc lamp with resistors below. The camera is shown in position under the tank; with this arrangement pictures were taken of the horizontal motion of the tracer drops.

TANK AND MIXER

The mixing tank was a glass cylinder 11.5 in. I.D. and 16 in. high cemented to the square, flat plate-glass bottom of a rectangular aquarium. The space between the cylinder and the outer rectangular aquarium was filled with water to eliminate the distortion inherent in viewing a cylindrical tank from the side. Optical tests showed that there was no significant optical distortion. Four 1-in.-wide baffles were installed adjacent to the tank wall at 90° intervals, cor-

responding to the conventional arrangement of baffles (3, 5). A 4-in.-diam., four-flat-blade standard (5) Mixing Equipment Company turbine (Figure 2) was used throughout the work. The disk of the turbine, which was 4 in. above the tank bottom, was rotated by a 1/2-in. stainless steel shaft attached to a 1/4-hp. shifting-brush, variable-speed motor. Accurate speed adjustments were made with a Variac in the power-supply line.

CAMERA

A 4- by 5-in. Speed Graphic camera having an f4.5 lens was used with Eastman Kodak

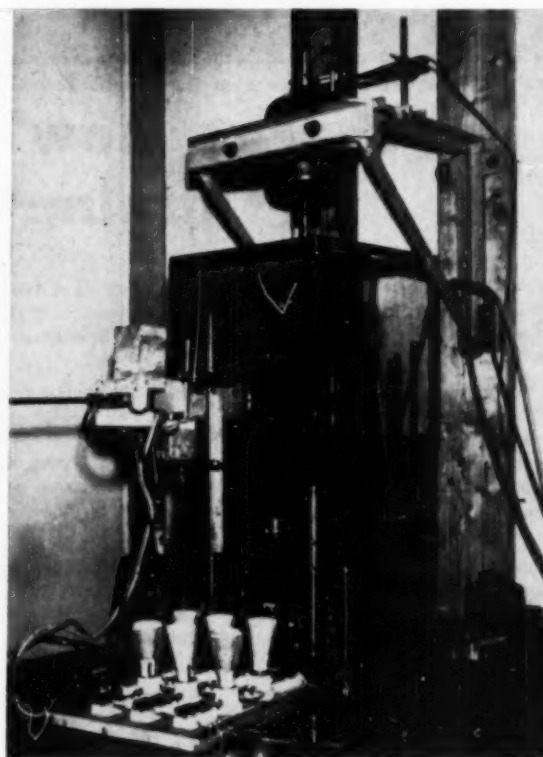


Fig. 1. Experimental equipment.

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LIGHT SOURCE

The required light intensity to permit photography under the experimental conditions was obtained from a carbon-arc light, which consisted of a rectangular chamber having carbon

holders at one end and an adjustable slit opening at the other end. The lamp was mounted on a stand with the slit in a vertical or horizontal position as desired. An additional adjustable slit barrier was provided at the tank wall. With the two slit barriers properly aligned, light issuing from the lamp was confined to a planar section which did not diverge appreciably. The arc lamp was placed with its front slit about 2 in. from the tank wall. The two arcs were connected in series and could be operated simultaneously or individually from a 110-v. D.C. supply. At full intensity the arcs consumed 50 amp.

TRACER PARTICLES

Considerable effort was expended to determine the most suitable type of tracer particles. The general requirements were that the particles should be small enough to follow the fluid motion at the same velocity as that of the fluid itself and yet large enough to be photographed distinctly. Furthermore, they had to have approximately the same density as the medium liquid

and to reflect sufficient light to photograph well.

The first successful results were obtained with liquid tracer drops made of dibutyl phthalate and kerosene, proportioned to the density of water. They were colored white with zinc oxide powder (150 mesh) for maximum light reflection. More recently small plastic spheres have been used successfully.

Experimental Technique

The cylindrical tank and outer shell were filled with 12 in. of water. The lamp and camera were positioned and adjusted and the turbine was started at the desired speed. Approximately 1 ml. tracer liquid was injected into the tank by means of a hypodermic syringe through a small capillary tube extending through the tank bottom. Shear action of the agitated liquid thus quickly reduced the tracer droplets to 0.02 to 0.04 in. diam., a suitable size for photographing.

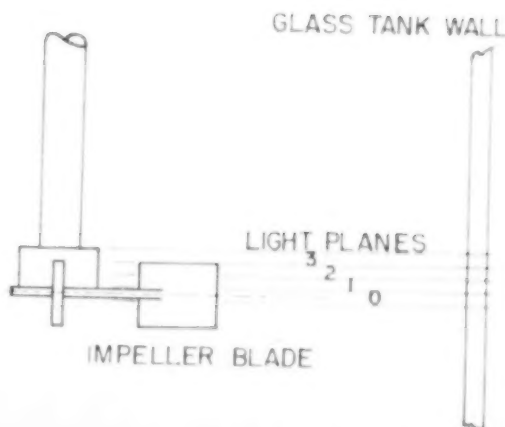


Fig. 5. Partial vertical cross section showing impeller, tank wall, and horizontal light planes.

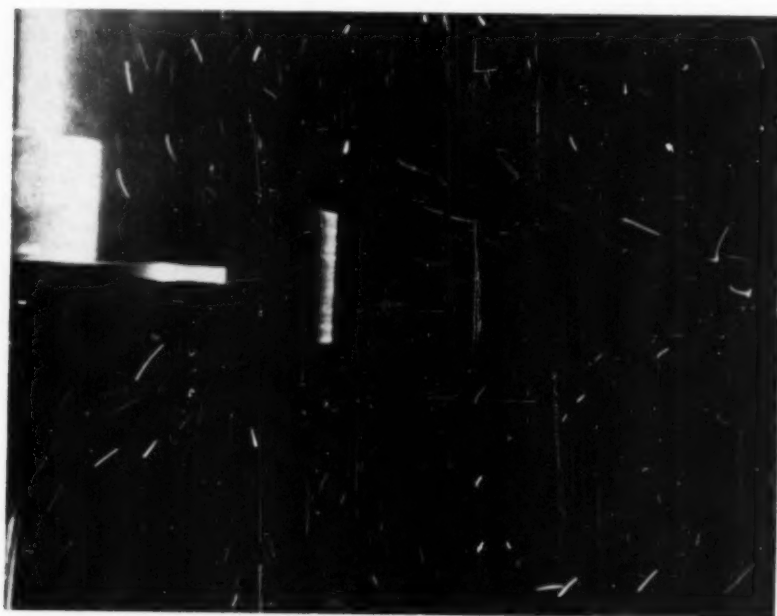


Fig. 4. Vertical-plane trace photograph.

Photographs were taken with two different camera positions. The first set included photographs taken through the tank bottom with horizontal-plane illumination. These showed the flow pattern and velocities in horizontal planes. The second set included photographs taken through the tank side with vertical plane illumination showing flow patterns and velocities in vertical planes. Typical photographs are shown in Figures 3 and 4.

Figure 5 is a partial front view of the mixing tank showing a cross section of the horizontal sections investigated. These sections represent horizontal planes of light approximately 3/16 in. thick extending across the tank and intersecting the turbine at the positions shown. The horizontal planes have been designated by the numerals 0, 1, 2, and 3 for data-tabulation purposes.

Photographs taken through the tank bottom show only the tracer droplets moving in the particular plane illuminated during the experimental run in question. Figure 3 is an actual bottom-view photograph taken with plane 0 illuminated and a turbine speed of 100 rev./min.

Because the horizontal-plane photographs had shown the existence of a velocity gradient between adjacent turbine blades, vertical-plane pictures were taken at three different positions between the blades by adjusting the position of the shutter-tripping device on the shaft. The three positions are shown in Figure 6; the first position shows the light in line with a blade; the second position is 30° back of the blade; and the third position 60° back.

The experimental work was planned so that the data would permit calculation of the volu-

metric flow and of the radial, tangential, and vertical velocity components of flow at any point in the discharge stream of the turbine. Fluid velocities were found to be symmetrical with respect to the vertical midpoint of the turbine.

Approximately six photographs were taken for each plane of illumination. It was found that approximately five hundred tracer drop streaks per photograph were desirable from an analysis

mixing

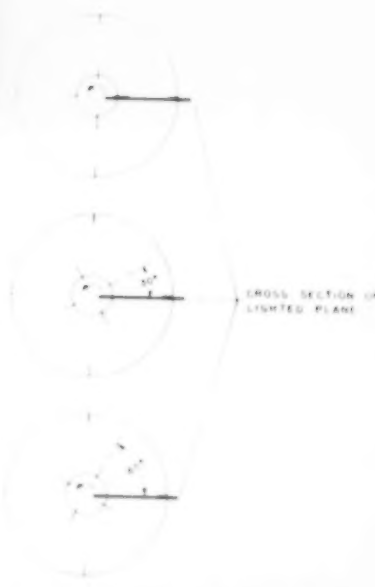


Fig. 6. Top views, vertical-plane illumination for three turbine positions.

point of view; therefore, several exposures were made on one negative, the number of tracer drops in the tank not being great enough to cause interference in photographing. The experimental work encompassed some 175 separate photographs equivalent to 350 to 450 exposures.

Analysis of Negatives

HORIZONTAL-PLANE ILLUMINATION

Analysis of the negatives consisted in projecting on paper, marking the traces, and resolving them into their radial and tangential components. These component vectors were then measured and the measured lengths converted to lineal velocities by means of a calibration factor. The following terms are used hereafter: *quadrant*, a 90° section of the tank encompassing the distance between two adjacent impeller blades; *section*, one-sixth of a quadrant; *annulus*, an annulus $\frac{1}{8}$ in. wide; *radial distance*, distance from tank axis to midpoint of an annulus.

Figure 7 shows one of the coordinate sheets used for analysis of the horizontal-plane photographs. It consists of a quadrant divided into six sections. Five annuli have been drawn, the first immediately adjacent to the periphery of the turbine and the remainder at 1-in. radial increments. For reference purposes the sections are numbered clockwise from 1 to 6, and the annuli are designated by the letters A, B, C, D, and E, beginning with the innermost annulus.

The processed 4- by 5-in. negatives were projected upon these coordinate sheets, the projected turbine image being enlarged to one and a half times actual size. All the tracer-drop streaks which began, passed through, or terminated in an annulus were pencil traced on the coordinate sheet. The traced velocity vectors were resolved into radial and tangential components, as shown at annulus A.

For each annulus the lengths of the radial components in a given section from all the photographs taken at a particular speed were averaged arithmetically, and the arithmetic mean of the averages of each section of a given annulus was then determined. This gave the average for the quadrant at the radial distance corresponding to the particular annulus. All the average values for a particular speed and plane of illumination were then tabulated. The tangential components were treated in like manner.

To convert drop-streak length to velocity it is necessary to know the time of exposure or the velocity of some part of the system. The velocity at the turbine-blade tip can be found accurately by calculating πDN , where D is the tur-

bine diameter and N the rotational speed.

Figure 3 shows the blurred images of two turbine blades as they moved during the exposure. The streak made by the tip of each blade is clearly pictured. Such streaks appear on the coordinate papers (Figure 7) as the blade-streak line S . Thus the length of S divided by πDN gives the time of exposure. Any streak length (or component) divided by the time of exposure gives the average velocity of the particle making the streak. A more convenient way to determine the velocity v , corresponding to each drop-streak length L , is to use the ratio of $\pi DN/S$ as a constant for any streak or component on a coordinate sheet. Then

$$v/L = \pi DN/S$$

and

$$v = L\pi DN/S \quad (1)$$

VERTICAL-PLANE ILLUMINATION

The vertical-plane-illumination photographs were analyzed in the same manner as the horizontal-plane ones. The negatives were projected onto coordinate sheets made up to show the vertical sections; all the projected streaks which began, passed through, or terminated in the planes 0, 1, 2, or 3 at the annuli A, B, C, D, or E were pencil traced. An illustration is shown in Figure 8. The

traced vector streaks were resolved into horizontal and vertical components; the vertical components were measured and used in the correlations. The vertical component lengths were averaged for each of the regions formed by the intersection of a horizontal plane and an annulus. In the averaging, downward velocities were considered negative and upward velocities positive. These average values were then multiplied by the proper factor to convert them to absolute velocities.

TRACES WITHIN THE ILLUMINATED PLANE

Since the flow was not parallel to the plane of light at all times, a tracer particle may have entered or left the illuminated plane during the exposure period. If this happened, the drop would photograph only while in the illuminated plane. The photographed streak would not represent the total distance traveled during the exposure time. Errors of this type were eliminated, for all practical purposes, by adjusting the exposure time so that the photographed streaks had vertical components less than the width of an illuminated plane (as determined in the vertical-plane photographs). Because the boundary of the illuminated plane is not completely sharp, owing to some light diffusion, a streak made by a drop which leaves the plane does not

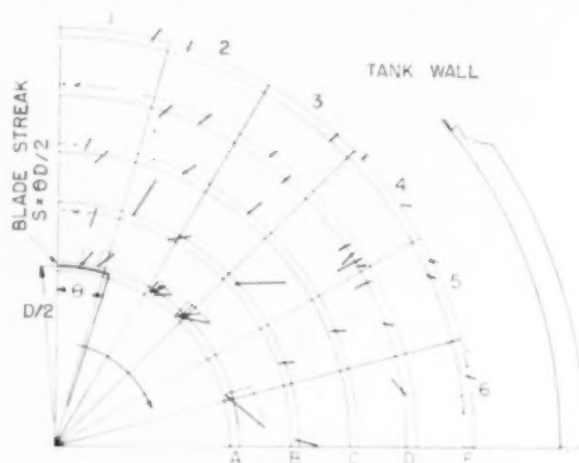


Fig. 7. Horizontal-plane coordinate sheet showing traced streaks.



Fig. 8. Vertical-plane coordinate sheet showing traced streaks.

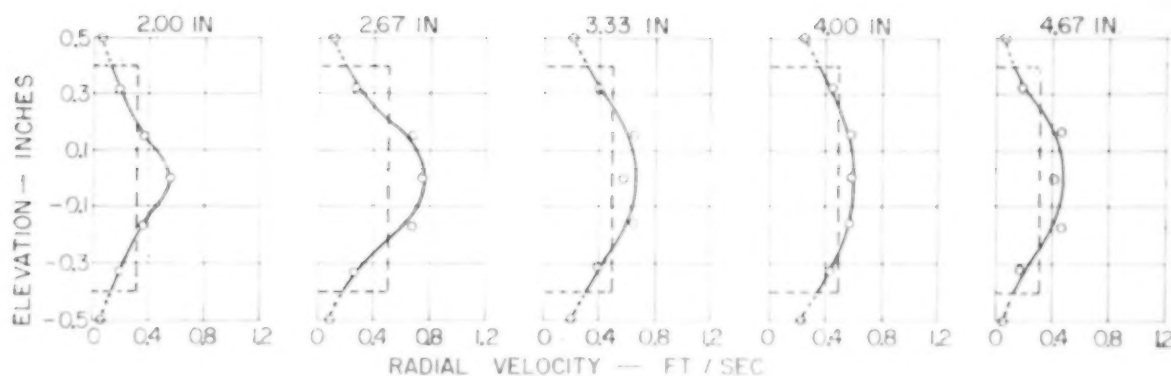


Fig. 9. Velocity profiles in the discharge stream.

blank out abruptly, but rather fades out slowly. For this reason it was possible to detect the streaks made by a drop leaving or entering the plane; these streaks were not considered in computing the average velocities.

Results

It was arbitrarily decided to express flow in terms of radial-component flow; hence radial components of the traces formed the basis of all the derived flow data.

RADIAL VELOCITIES

Values of the radial component of velocity at various radial distances in the discharge stream for a turbine speed of 100 rev./min. are shown in Figure 9 in the form of velocity profiles. The abscissa is the radial component in feet per second; the ordinate is the elevation in inches, above or below the vertical midpoint of the turbine blade. The top and bottom edges of the turbine blade are at ± 0.4 in. respectively. The average radial velocity across the width of the turbine blades is indicated by a dotted line. The radial distance from the tank axis to the point in question is indicated above the ordinates. The following general conclusions can be drawn from these curves.

The velocity-distribution curves tend to flatten out as the radial distance increases. This flattening out of the pro-

files is shown quantitatively by the ratio of the average velocity to the maximum velocity (\bar{v}/v_{max}).

These ratios are shown in Table 1 for the various turbine speeds and radial distances.

The ratio (\bar{v}/v_{max}) is independent of turbine speed but increases as the radial distance increases. The variations in this ratio at various turbine speeds are small enough to be attributed to experimental error, and no definite trend could be found. The fact that the ratio is independent of speed is of considerable significance in that it greatly reduces the experimental work and calculations necessary in further analysis. It means that complete results for dimensionally similar turbines can be obtained by simply photographing with plane 0 illuminated, calculating the maximum

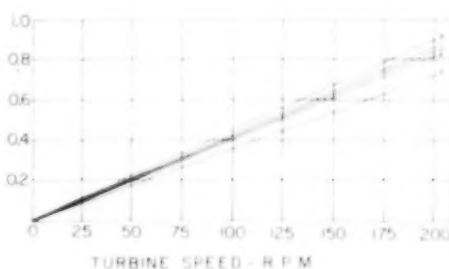


Fig. 10. Average radial velocity of each annulus for different turbine speeds.

mixing

radial velocities from these photographs, and then obtaining the average radial velocities by multiplying by the proper ratio factor.

Figure 10 is a plot of average radial velocity across the turbine blade vs. turbine speed. Analysis of these curves shows that the average radial velocity increases slightly as the radial distance increases from A to B (Figure 7) and then remains nearly constant until a radial distance of D is reached. This conservation of velocity head can be attributed to the vertical inflow which is due to entrainment.

There is a variation in the radial component of velocity (v_r) with angular position between adjacent turbine blades as shown in Figure 11. The velocity values shown are the maximum velocities as determined from horizontal-plane photographs. Three curves at different radial distances are shown. Examination of these curves reveals that at the turbine periphery (A) there is a high peak in the curve at a point about 50° ahead of the rotating blade. At this point the radial velocity is approximately 38% above the average value, and the

Table 1.—Ratio of Average to Maximum Radial Velocity \bar{v}/v_{max}

Turbine speed, rev./min.	\bar{v}/v_{max}				
	Radial distance, in.				
	2.00	2.67	3.33	4.00	4.67
100	0.57	0.68	0.79	0.88	0.83
150	0.69	0.73	0.76	0.86	0.85
200	0.66	0.75	0.76	0.77	0.75
Avg.	0.64	0.72	0.77	0.84	0.81

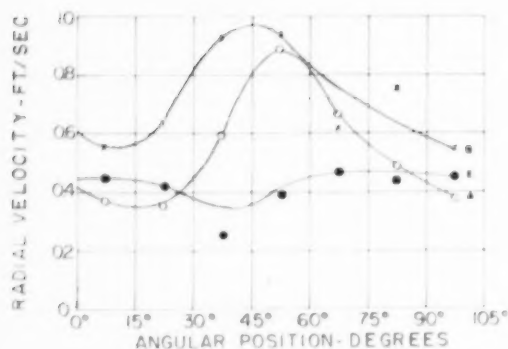


Fig. 11. Radial velocity for angular position between blades.

effect is that of a pulsation. The occurrence of this maximum persists as the radial distance is increased until a point is reached two thirds of the distance to the tank wall (at annulus *D*). Beyond annulus *D* the flow is uniform with respect to angular position, and there is no noticeable pulsation.

TANGENTIAL VELOCITIES

The effect of the magnitude of the tangential-velocity (v_t) components can be shown by computing the velocity-vector angle ϕ and then examining the variation of ϕ with angular and radial position. The angle ϕ is defined as

$$\phi = \arctan \frac{v_t}{v_r}$$

Figure 12 is a plot of ϕ vs. angular position. The vector angle increases to a maximum at a point about 60° in front of a turbine blade.

The relation between the quadrant average vector angle and radial distance is shown in Figure 13. The vector angle

rapidly decreases from a value of 53° at the turbine periphery to a value of approximately 22° at a radial distance of 5 in. This decrease in the vector angle with increasing radial distance is consistent with the general concept of the effect of baffles on the flow pattern in a cylindrical tank. Visual observation shows that baffles decrease the tangential, or swirling, flow and thereby increase radial flow. This is confirmed by the present quantitative data.

RADIAL VOLUMETRIC FLOW

The volumetric discharge of the turbine is defined and used herein as the radial volumetric flow emerging from the cylindrical area formed by the product of the turbine circumference, πD , and the blade width, W . The flow at various radii *A*, *B*, etc., is arbitrarily defined as the average radial velocity multiplied by $2\pi R$ times the turbine-blade width W .

Figure 14 shows a plot of volumetric flow of the discharge stream vs. turbine speed. The parameters are radial dis-

tance (*A*, *B*, *C*, *D*). These curves show that the volumetric flow is directly proportional to the turbine speed at all the radial distances for which data were obtained. The total volumetric flow increases with increasing radial distance up to a radial distance of 4 in. (annulus *D*), after which it drops off. Therefore the maximum volumetric flow occurs at a radial distance of approximately 4 in. regardless of the turbine speed. This distance corresponds to approximately two thirds the distance from the tank center to the tank wall. The curve for annulus *C* has been omitted for clarity; it lies just below curve *E*.

The difference between the maximum-discharge-stream flow (at *D*) and the volumetric-discharge flow at the turbine periphery is shown in Table 2. This difference is the vertical induced, or entrained, inflow; thus the stream flow at a particular annulus may be thought of as volumetric discharge of the turbine plus the induced flow. Table 2 shows the total induced inflow from *D* to *A* to be approximately equal in magnitude to the volumetric discharge flow at the turbine periphery for all turbine speeds. The sum of this induced flow and the flow at *A* can be considered as a volume of material that is intimately mixed in the discharge stream. This total mixed volume is approximately twice the peripheral discharge flow of the turbine. Induced flow is due to entrainment by momentum transfer and turbulence, just as in the case of entrainment by freely expanding submerged jets (1, 5).

Also shown in Figure 14 is a value computed from the data of Rushton, Mack and Everett (4), the only published data on volumetric-flow discharge from a turbine impeller. They used a volumetric-displacement technique to measure the flow from a 6-in., four-

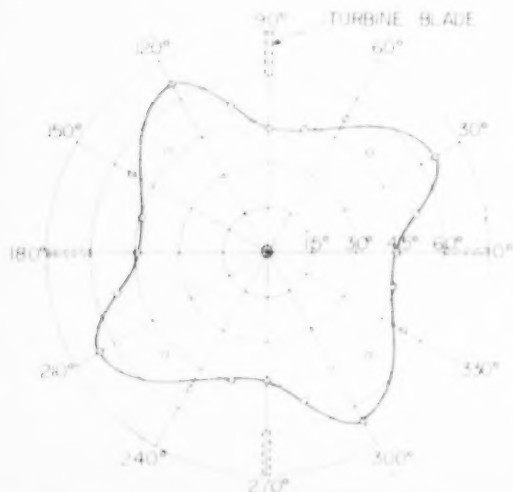


Fig. 12. Angle of flow for position between blades.

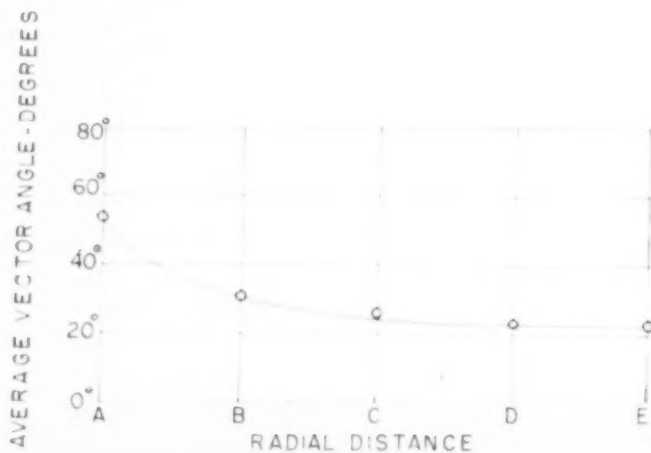


Fig. 13. Angle of flow at various radial distances.

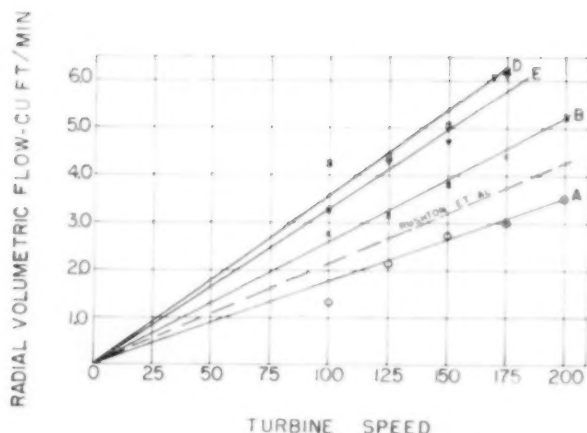


Fig. 14. Volumetric flow at various radii as a function of speed.

blade turbine; the values multiplied by the cube of the impeller-size ratio give the values shown by the curve. These data fall between the present values for radial distances *A* and *B* and are considered to be in reasonably good agreement with the present results. The technique used by Rushton, et al., should give the displacement at the periphery of the turbine, since their experimental method precluded measurement of the induced inflow.

VERTICAL VOLUMETRIC FLOW

The induced vertical inflow was calculated independently from the average vertical-velocity components obtained from analysis of the vertical-plane photographs. Figure 15 shows a typical plot of the vertical-velocity components vs. radial distance. All values are for fluid flowing through the horizontal plane at the top edge of the turbine blades. Positive values indicate upward flow and negative values, downward flow. The curve shows the flow to be downward (into the radial stream) until a radial distance of approximately 4 in. (annulus *D*). At this point the vertical velocity is zero, and from this point to the tank edge the velocity is upward with increasing magnitude because of the upward flow of the entire upper half

of the stream at the tank wall. These results are in agreement with those obtained from the horizontal-plane photographs, which show an increase in radial flow in the impeller-discharge stream up to a radial distance of 4 in. The net vertical volumetric flows were calculated and checked, the values of induced vertical inflow being shown in Table 2.

Conclusion

It should be noted that the amount of flow (in a radial direction) is a function not only of the speed of the turbine but also of the number of blades, size of the turbine, position of the turbine, and number and size of the baffles. The data herein cover only the flow within the vertical limits of the turbine-blade width; it is known that there is considerable radial flow in the discharge stream outside this limiting area, and these flows are now under study by the same trace technique.

The results show that the volumetric discharge is directly proportional to impeller speed. The discharge stream entrains surrounding fluid and the experimental technique permits the measurement of this induced flow. Velocity directions, distributions, and averages have been determined for one size and position of turbine.

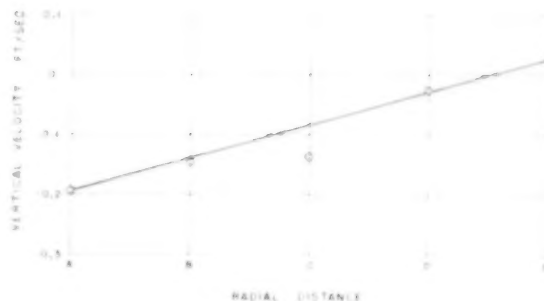


Fig. 15. Vertical-velocity components at various radii.

Acknowledgment

This work was made possible by the support of the Mixing Equipment Company, Rochester, New York, through a fellowship in chemical engineering research at the Illinois Institute of Technology.

Notation

A = cylindrical surface area of an annulus

mixing

D = turbine diameter

L = length of drop streak

N = turbine speed

Q = volumetric-flow rate

A, B, C, D, E = annuli at various radial distances

S = length of streak made by outer edge of moving turbine blade

v = velocity, instantaneous

\bar{v} = average velocity

v_r = radial velocity

v_t = tangential velocity

W = width of turbine blade

R = radial distance to an annulus

0, 1, 2, 3 = designation of horizontal illuminated planes

ϕ = velocity vector angle

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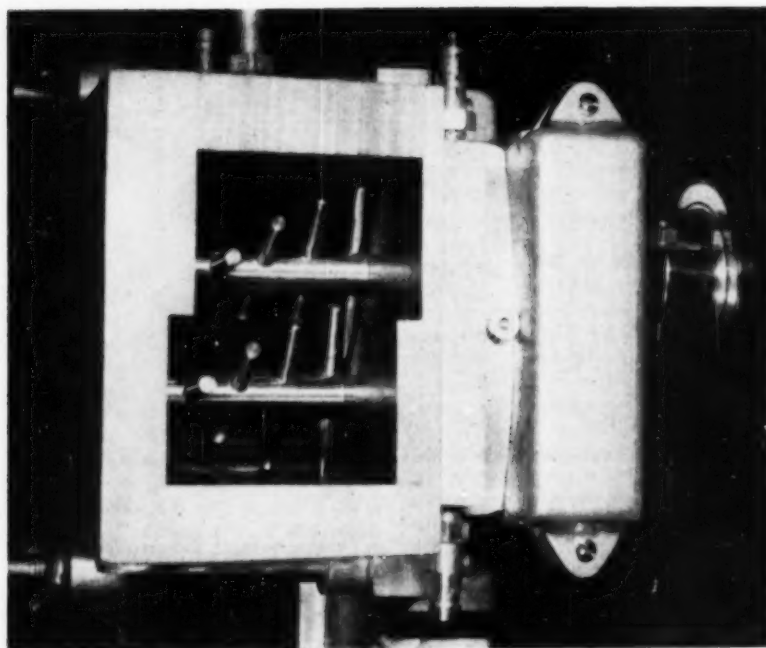
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Presented at A.I.Ch.E. San Francisco meeting

Table 2.—Calculated Induced Vertical Volumetric Flow

Turbine speed, rev./min	Periphery flow <i>A</i> , cu.ft./min	Maximum flow <i>D</i> , cu.ft./min	Induced flow <i>D-A</i> , cu.ft./min	Ratio <i>D/A</i>
100	1.75	3.45	1.70	1.97
150	2.62	5.15	2.53	1.96
200	3.52	6.92	3.40	1.96

Fig. 3. Detail of finger-prong mixer; note staggered positions of prongs on each shaft.



evaluating performance characteristics of mechanical mixing processes: the dextrose-kaolinite-water system

Alan S. Michaels and
Vytautas Puzinauskas

Massachusetts Institute of Technology

Factors Affecting Solid-Solid Mixing

A. DRY POWDERS

If two dry, free-flowing, finely divided solids *A* and *B* are blended with each other in, say, a paddle-type mixer, the mixing process basically involves the continued transport of solid *A* or *B* (or a mixture of the two) from one region to another region of the mass where the relative amounts of *A* and *B* present are different. The rate of attainment of uniformity of distribution will depend thus on (among other variables) the volume of mixture displaced in each revolution of the paddle (relative to the total volume of mixture present), the rate of rotation of the paddles,

Although the process of mechanically mixing two or more substances is one of the oldest of unit operations, relatively little progress has been made in the development of scientific methods for predicting mixer performance, or for designing mixing devices which are peculiarly well suited to individual mixing problems. There are two obvious reasons for this situation: (1) the number of variables which enter into mixing operations are usually large and difficult to control, and (2) reliable quantitative methods of characterizing goodness or poorness of mixing are not readily adaptable to experimental measurement.

Though considerable and reasonably fruitful study has been made of mixing of liquids with liquids, or solids with liquids (4, 5, 6, 7), little work has been done on the mixing of granular solids with other granular solids in the presence (or absence) of small amounts of liquid. This problem is of importance in a number of fields, especially in ceramics, plastics compounding, fertilizer blending, concrete mixing, and soil treatment. The object of this work has been to examine a system of this last type, to select a reliable measure of mixture uniformity, and to determine the dependence of mixer performance upon a few important and controllable variables.

the clearance between the paddles and the walls of the mixing vessel, and the shape and angle of attack of the paddles. For a mixing apparatus of fixed size and design the rate of attainment of uniformity will depend on (a) the speed of the mixing blades, and (b) the volume of solids present. Within certain limits of blade speed, the rate of mixing is expected to depend largely on volumetric rate of displacement of solid, and hence to be proportional to blade speed. Above or below these arbitrary limits of velocity, however, the character of the solid transport will change (e.g., from "sliding" at low speeds to "projection" at high speeds), and the dependence of mixing rate on blade velocity may become discontinuous. Similarly, the total volume of solids present will have a pronounced effect on the efficiency of the mixing process. If the mixer contains too little material, the full displacement capacity of the blades will not be utilized, and a large fraction of the batch may remain stagnant; both of these factors will contribute to lower mixer efficiency. If, on the other hand, the mixer is overloaded, the fraction of the batch displaced by the blades per unit time will be low, and some of the solid may seldom contact the blades; this, too, will result in low efficiency. Consequently, one would expect to find a maximum in the rate of attainment of mixture uniformity at a clearly defined mixer content; this optimum volume will, of course, depend on the characteristics of the mixer and of the solids being mixed.

Another important variable affecting rate of attainment of homogeneity in mixing is the ratio of quantities of solids being mixed. It is obviously easier to attain mixture uniformity when the substances involved are added in approximately equal volumes than when one component is present in small amount. Evidently, it becomes increasingly difficult to obtain homogeneity as the volume fraction of one component of a mix is reduced to lower and lower values. Consequently, rate of attainment of mixture homogeneity can be expected to increase rapidly as the volume ratio of solids being mixed approaches unity from either very high or very low values.

In the mixing of dry, free-flowing powders homogeneity can be achieved merely by solid transport, and the energy requirements for the mixing operation need to be no larger than the work required to overcome gravitation forces associated with the movement. Energy expended as shear within the mass is poorly utilized in improvement of homogeneity; hence the most efficient mixers for dry powders are tumblers or rotating bin devices in which energy dissipation by shear is at a minimum. It appears not unlikely, therefore, that dry powder

mixing would be among the simplest and cheapest (in power consumption, if not in equipment) of the mixing processes involving granular solids.

B. MIXING INVOLVING WET SOLIDS

When a mixing process involves the blending of two solids, at least one of which is initially wet, the character of the mixing operation and the rapidity of homogenization of the mixture depend to a great extent on the rheological properties of the wet solid. Changes in properties that a finely divided solid frequently undergoes when wet with varying amounts of a liquid in which the solid is insoluble are described qualitatively as follows:

(1) Pellet-and-Powder State

If a small quantity of liquid is added to a dry, free-flowing powder (e.g., water to clay), the solid tends to ball up in small pellets which are frequently quite resistant to disintegration. Frequently at low liquid contents, these pellets are imbedded in a matrix of essentially dry powder, so that efforts to disrupt them are also impeded by the "cushioning" action of this matrix. Solid in this condition is still free flowing in the macroscopic sense, although the flow unit is no longer a single ultimate powder particle.

(2) Pellet State

As the liquid content of the powder is increased still further, more and more pellets are formed at the expense of residual dry powder, and the mixture assumes a coarse, granular appearance. Although the pellets do not cohere when brought into contact with one another (i.e., the mixture is still free flowing), stirring of the mass usually results in breakdown of the pellets into smaller aggregates.

(3) Plastic State

Further increase in liquid content is accompanied by marked change in character of the mixture. Two clumps of material will now cohere if brought into contact. The mixture loses its granular appearance, and becomes more or less homogeneous; it is highly resistant to shear, and behaves like a plastic solid in that it will fracture if subjected to high stress, but flow without rupture under lower stresses. Potter's clay and modeling clay are examples of solid-liquid mixtures of this consistency.

(4) Sticky State

As the liquid content is increased even more, the mass begins to behave like a paste. It becomes shiny and sticky, often adhering tenaciously to foreign solid surfaces. It will withstand only small distortive forces without undergoing flow, and will no longer exhibit fracture under load.

(5) Liquid State

Continued addition of liquid to this mixture

renders it more and more fluid in character; the apparent viscosity of the mass decreases, it flows merely under its own weight, and tends to drain from vertical surfaces. In other words, the mixture once again becomes free flowing but in a sense quite different from that of a dry powder.

This transition is illustrated in Figure 1, which shows masses of pure kaolinite containing varying proportions of water.

It should be clear now that the rate of attainment of homogeneity in the mixing of a small quantity of dry powder *A* with a wet powder *B* will depend to a large extent on the amount of liquid present. If the wet solid is in the pellet-and-powder state, the rate of homogenization (in a paddle or blade mixer) with respect to the dry powder fraction of the mixture will be about the same as that of the dry powders alone; however, incorporation of *A* into the pellets of *B* will be an extremely slow if not impossible process. Hence, in mixing such a system there will be a rapid initial improvement of homogeneity, followed by a period in which little to no improvement in uniformity takes place. If solid *B* is in the pellet state, mixing must be accomplished by rupture

mixing

of the pellets and deposition of solid *A* on the pellets. Uniformity is achieved by continued pellet breakdown and reformation in contact with solid *A*. It would appear that homogenization would be accomplished relatively more slowly but somewhat more regularly than with solid in the pellet-and-powder state.

When solid *B* is in the coherent plastic state (3), dispersion of solid *A* involves not so much simple solid transport as shearing of solid *B* and deposition of *A* particles at the planes of shear. Clearly if the critical shear stress which initiates flow of the mass is high, the shear force set up by the mixer blades will also be high, and will be propagated to regions of the mixture quite remote from the blades themselves; in other words, a larger fraction of the mixture volume will be in motion than if there is little or no cohesion to the mass. Other things being equal, the rate of homogenization under these conditions might be expected to be quite rapid—certainly more so than with a pellet or pellet-and-powder system. Obviously, the power requirements for mixing under these conditions will be greater than for either drier or wetter mixtures.

If solid *B* is in the sticky state (4), and the mixing process is of the same character as that described for plastic masses,

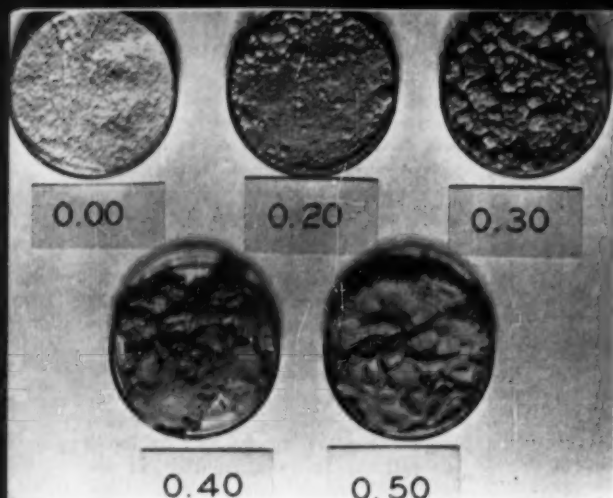


Fig. 1. Changes in texture and appearance of kaolinite-water mixtures with increasing water content. Numbers indicate water : clay ratio.

the amount and extent of shear achieved during mixing is considerably reduced, so that dispersion of solid *A* into *B* may be confined to the immediate vicinity of the mixer blades.

Furthermore, because of the sticky character of the mix, material near the walls of the mixing chamber (and, for that matter, the material in direct contact with the mixer blades themselves) may never be put in motion and brought into contact with the added ingredient. Consequently, it could be predicted that the efficiency of the mixing process under such conditions would be quite low.

If solid *B* is in the liquid state (5), shear forces set up by the mixer blades, though they are low in magnitude, can establish convection currents in the body of the material which will keep a large fraction of the mass in motion. This will facilitate mixing of *A* and *B*, and hence improve the rate of attainment of uniformity.

A summary of these general trends in rate of homogenization and efficiency of utilization of mixing energy with liquid content perhaps can best be presented tabularly as shown in Table A.

C. EFFECT OF MOLECULAR DIFFUSION

If solid *A* is soluble in the liquid

present (as is frequently the case), homogenization will evidently be aided by molecular diffusion of the solute. At low liquid contents where the liquid phase is discontinuous (in the pellet-and-powder or the pellet state), diffusion can contribute little to attainment of uniformity during the initial stages of mixing; however, toward the end of the mixing process, molecular diffusion may be the most rapid means by which true homogeneity is achieved. When a mixture is in the pellet-and-powder state, it is not impossible that solution of *A* can actually cause a decrease in mixture uniformity with time. If the soluble additive is distributed rapidly and uniformly through the powder fraction of the mixture, the pellets can pick up on their surfaces and dissolve (by virtue of their higher liquid content) the additive. The net result of this process will be the extraction of the additive from the powder fraction of the mixture and its concentration in the pellets, with transient decrease of homogeneity.

At higher liquid contents where the liquid phase is continuous, perfect mixing without any mechanical effort whatsoever can be realized solely by diffusion; obviously, the rate of diffusional blending is normally extremely slow, and

so the contribution of diffusion to homogenization by any ordinary physical process may be negligible. It probably is safe to conclude that the effect of diffusion on rate of attainment of mixture uniformity will always be favorable, but will be of significance only in inefficient mechanical mixing processes.

Characterization of Mixture Homogeneity—The Uniformity Index

A mixture could be defined as homogeneous if any sample of the mixture has the same composition and properties as any other. Evidently every mixture could be designated as homogeneous by this definition, provided the samples selected for analysis were large enough. Hence, it is necessary to specify the scale of homogeneity in terms of size of sample chosen for analysis. The highest attainable degree of homogeneity would thus be achieved when the composition is the same for all samples of the same magnitude as the ultimate particles of the mixture.

The scale of homogeneity which should be employed in evaluating a particular mixing process will depend largely on the use to which the final mixture will be put. If the mixture is a fertilizer blend, the scale of uniformity need not be nearly as small as, for example, that of a medicinal ointment. The scale used should therefore be smaller than the smallest volume of a mixture which will be employed or involved in a subsequent process or reaction.

The deviation of a mixture from true homogeneity can be expressed as the mean deviation of the volume concentration of one component in a number of randomly selected samples (of fixed volume) from the mean concentration of component *A* in the mixture. If C_A is the concentration of *A* in a random sample of volume *v*, *n* the number of samples analyzed, and C_A^m the mean concentration of *A* in the mixture, then D_v , the fractional root-mean-square-deviation, is given by:

$$D_v = \sqrt{\frac{\sum_n (C_A - C_A^m)^2}{n [C_A^m]^2}} \quad (1)$$

The value D_v could be used directly as a measure of mixture uniformity since it varies from a finite value to zero as the mixture becomes more nearly homogeneous. A difficulty arises in its use, however, in that its value for the unmixed state (i.e., the condition when all of component *A* is present as a single "blob" in the mixture) is dependent upon the volume fraction of *A* added. If D_v^0 represents the value of D_v at no mixing, it can be shown that:

Table A.—General Trends in Mixing Characteristics

(Powder *A* to be blended with a mixture of *B* + Liquid)

Increasing Liquid Content of <i>B</i>						
Physical appearance:	Powder	Pellet + Powder	Pellet	Plastic	Sticky	Liquid
Rate of homogenization:	Rapid	Slow	Very Slow	Rapid	Slow	Rapid
Power input:	Low	Low to Moderate	Moderate	High	Moderate	Low
Efficiency of utilization of mixing energy:	Very High	Fair	Fair to Poor	Very Poor	Poor to Fair	High

$$D_v^c = \sqrt{\frac{1 - C_A^m}{[C_A^m]}} \quad (2)$$

Dividing (1) by (2),

$$\frac{D_v}{D_v^c} = I_v = \sqrt{\frac{\sum_{i=1}^n (C_A - C_A^m)^2}{n(1 - C_A^m)(C_A^m)}} \quad (3)$$

The value I_v , the Uniformity Index, is a convenient measure of mixture homogeneity since it has (irrespective of the value of C_A^m) a value of unity for the completely unmixed state, and a value of zero for the completely mixed condition. Also, I_v is independent of n , the number of samples taken, provided the samples are truly random and representative of the mixture. An analogous expression has been derived by Danckwerts (2), defined by him as the intensity factor in mixing.

The Uniformity Index at any stage in a mixing process thus can be determined from (1) analysis of a number of random samples for one component being mixed, and (2) the knowledge of the mean concentration of that component. In the mixing studies described below, six 1-cc. samples were analyzed to determine each value of I_v reported. The selection of this number of samples and sample volume was made largely on a basis of economy of effort and ease of analysis. Smaller volumes of mixture were found to be difficult to measure and analyze accurately; analysis of a larger number of samples appeared to add little to the consistency of the data. It appears likely that these practical considerations will often have greater influence upon selection of sample volume and number of samples taken than will the theoretical considerations just described.

Mixing Characteristics of Dextrose-Clay-Water Systems—Experimental

A. VARIABLES STUDIED

This investigation was aimed at determining some characteristics of mixing a water soluble powder with water-wet kaolinite. The effect on the mixing process of only two variables was examined: (1) initial water content of the clay, and (2) volume of solids mixed. Other controllable variables influencing mixing were held essentially constant; these include: (1) the chemical nature of the water soluble additive, (2) the concentration of additive, (3) the type of mixer, and (4) the mixer speed.

B. MATERIALS USED

The kaolin used in this work is a highly refined product prepared by the R. T. Vanderbilt Co., New York City. It is essentially pure kaolinite (Al_2Si_2

$O_{10}(OH)_8$) and shows the following Atterberg limits:

	Plastic Limit % (± 1)	Liquid Limit % (± 1)
Kaolinite	31.2	50.2
Kaolinite + dextrose (10 g./100 g. clay)	27.1	45.2

The water soluble powder employed was U.S.P. dextrose. Selection of dextrose was based on a recognition of the fact that nearly all water soluble electrolytes alter the electrokinetic potential of clays, and hence their degree of dispersion. A nonionic water soluble solid such as a simple sugar was expected to have a

minimum effect on the rheological properties of clay-water systems.

To permit mixture analysis by colorimetric means, the dextrose was colored uniformly with a small amount of picric acid (approximately 10 mg./g. dextrose) by slurrying the sugar in a solution of this compound in ethanol, draining and allowing the solvent to evaporate. Although picric acid is not a particularly intense dye, it was found to be the only one of a large number of water soluble compounds which was not significantly adsorbed by the clay.

In order that the colorimetric analysis of picric acid concentration in a sample be truly representative of the dextrose concentration, it is of course necessary that both compounds be present in the same ratio in the mixture sample as in the original dye-tagged dextrose. This necessitates (a) that both compounds dissolve in the clay-water mix with equal rapidity, and (b) that their ratio of diffusion be nearly equal. Inasmuch as dextrose dissolves extraordinarily rapidly in water, as does picric acid at the very low concentration employed here, and inasmuch as molecular diffusion appears to contribute little to mixing under conditions studied in this work, the assumption that the picric acid concentration was a direct measure of dextrose concentration seemed justifiable.

C. MIXING EQUIPMENT

The device which was employed for mixing studies is a variable speed, torque-recording, temperature-controlled finger-prong mixer (a

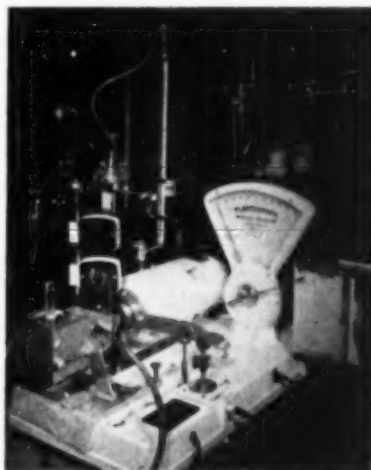
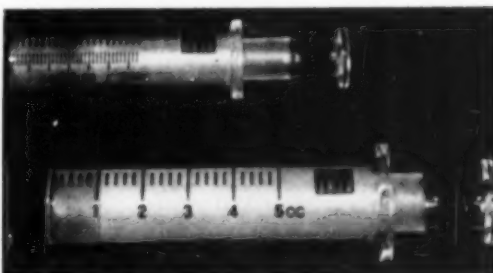


Fig. 2. Mixing apparatus: the Brabender Plastograph.

Figure 3 is on page 604.



mixing

Fig. 4. Mixture-sampling syringes. The movable piston facilitates expulsion of sticky or plastic solids.

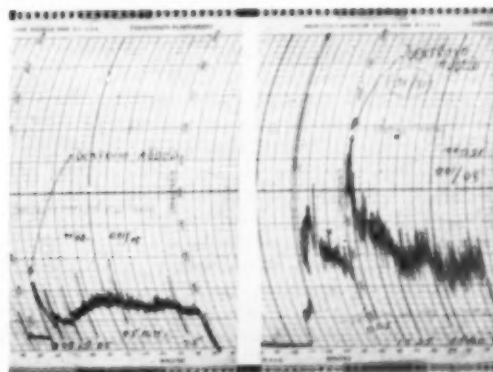


Fig. 5. Representative torque-time strip. Charts for kaolinite-water-dextrose mixing. Left: water-clay ratio = 0.20; mixture volume = 180 cc. Right: water-clay ratio = 0.30; mixture volume = 150 cc.

Plastograph, manufactured by the Brabender Corp.), shown in Figure 2. The mixer itself (Figure 3) consists of a chamber 7.2 cm. wide by 10 cm. long by 10 cm. deep, in which rotate on horizontal axes two 10-finger spindles. The fingers (0.635 cm. in diam.) project 2.22 cm. beyond the 1.59-cm. diam. shafts. One spindle rotates 1.5 times as fast as the other, so that the total volumetric displacement per revolution of the slower spindle is approximately 420 cc. The volumetric capacity of the mill when the fingers (in a vertical position) are just completely immersed in the mill contents is 400 cc.

Throughout the tests, the mill speed was held constant at 60 rev./min. for the slow-speed spindle. The mill is water-jacketed, and the temperature was held at $30 \pm 1^\circ \text{C}$. throughout.

D. TEST PROCEDURE

1. In order to determine the effect of dextrose upon the rheological properties of kaolin-water mixtures, the following two experiments were performed:

A weighed quantity (260 g.) of dry kaolin was placed in the mixer, the power turned on, and water added in increments corresponding to 5 g./100 g. of clay; after addition of each increment, the steady state mixing torque was recorded. The water content range studied was from 0 to 50 g./100 g. of clay.

A similar experiment was performed employing initially a uniform mixture of 260 g. of dry kaolin and 26 g. of dry dextrose.

2. Measurements of the rate of attainment of mixing uniformity were conducted in the following manner: Batches of wet kaolin containing 20, 30, 40 and 50 parts of water/100 parts of dry clay were thoroughly mixed. These mixtures were placed in sealed jars and allowed to equilibrate for several days. Samples were then analyzed by simple gravimetric methods to check the water content, and the bulk density of each batch was determined by weighing samples which had been packed by hand into a known volume. A modified hypodermic syringe (Fig. 4) was used for the volumetric measurements. A selected volume of clay-water mix (varying between 120 and 320 cc.) was introduced into the mill, blended for a few minutes to insure proper distribution of the mass, and the steady state mixing torque recorded. The mill was stopped, and an amount of picric acid colored dextrose equivalent in weight to 10 g./100 g. of dry clay present, was spread in a narrow band between the pugs. The mill was then turned on, and a continuous torque vs. time curve recorded, examples of which are shown in Figure 5. At intervals throughout the mixing period (total time of mixing: 7.5 min. for most runs), the mill was stopped, and six 1-cc. samples removed with the syringe (see Figure 4). Each sample was weighed and then transferred to a tube containing 25 cc. of distilled water. This mixture was agitated to disperse the clay thoroughly, centrifuged, and a sample of the supernatant liquid removed for colorimetric analysis. Color intensity measurements with an electrophotometer permitted calculation of the dye, and hence dextrose-content of the original sample.

Table 1. Representative Uniformity Index Data

Clay paste used: 29.6 g. $\text{H}_2\text{O}/100 \text{ g. dry clay}$. Measured paste density: $1.88 \pm 0.02 \text{ g./cc.}$

Volume clay used: 180 cc. = 336 g. paste, containing 261 g. dry clay.

Dextrose added: 10 g./100 g. dry clay, or 26.1 g. Assumed dextrose density: 1.30 g./cc.; hence 20.1 cc. added.

Mixing Time min.	Weight of 1-cc. Sample g.	Photometer Reading	Calc'd Picric Acid Conc. mg./cc. soln.	-C'- Picric Acid Conc. in Sample mg./cc.	(C' - C'_m) mg./cc. (C'_m = 1.270)	(C' - C'_m) ²
0.5	1.806	37.5	0.0505	1.265	-0.005	0.00025
	1.858	37.0	0.0490	1.225	-0.045	0.00225
	1.850	42.3	0.0685	1.715	+0.445	0.270
	1.873	36.7	0.0480	1.200	-0.070	0.0049
	1.852	39.4	0.0575	1.235	-0.035	0.00125
	1.893	35.5	0.0445	1.110	-0.160	0.0256
Avg.: 1.855 \pm 0.019				Avg.: 1.29		Total: 0.3040
1.5	1.886	34.0	0.0405	1.015	-0.255	0.065
	1.888	36.5	0.0475	1.190	-0.080	0.0064
	2.004	38.4	0.0540	1.350	+0.080	0.0064
	1.883	37.8	0.0515	1.290	+0.020	0.0004
	1.884	36.8	0.0485	1.215	-0.055	0.00325
	1.883	35.0	0.0435	1.090	-0.180	0.0324
Avg.: 1.904 \pm 0.033				Avg.: 1.19		Total: 0.1139
2.5	1.887	37.3	0.0500	1.250	-0.020	0.0004
	1.876	38.4	0.0540	1.350	+0.080	0.0064
	1.871	37.8	0.0515	1.290	+0.020	0.0004
	1.896	37.5	0.0505	1.265	-0.005	0.000025
	1.869	38.0	0.0525	1.315	+0.045	0.00225
	1.881	37.5	0.0505	1.265	-0.005	0.000025
Avg.: 1.880 \pm 0.008				Avg.: 1.29		Total: 0.00950
4.5	1.872	37.9	0.0520	1.300	+0.030	0.0009
	1.871	37.5	0.0505	1.265	-0.005	0.000025
	1.840	37.9	0.0520	1.300	+0.030	0.0009
	1.872	38.2	0.0530	1.325	+0.055	0.00325
	1.908	38.0	0.0525	1.315	+0.045	0.00225
	1.895	37.5	0.0505	1.265	-0.005	0.000025
Avg.: 1.876 \pm 0.016				Avg.: 1.30		Total: 0.00735
7.5	1.859	37.8	0.0515	1.290	+0.020	0.0004
	1.878	38.0	0.0525	1.315	+0.045	0.00225
	1.853	37.4	0.0505	1.265	-0.005	0.000025
	1.843	37.5	0.0505	1.265	-0.005	0.000025
	1.908	37.8	0.0515	1.290	+0.020	0.0004
	1.944	37.9	0.0520	1.300	+0.030	0.0009
Avg.: 1.881 \pm 0.024				Avg.: 1.27		Total: 0.00400

C'_m = over-all mean picric acid conc'n for 30 samples = 1.270 mg./cc.

Calculated mean conc'n (based on dextrose added) = 1.23 mg./cc.

$$D_{111} = \sqrt{\frac{1 - C_m}{C_m}} = \sqrt{\frac{180}{20.1}} = 2.98$$

$$D_{111} = \sqrt{\frac{\sum(C' - C'_m)^2}{6(C'_m)^2}}; \quad I_{111} = \frac{D_{111}}{D_{111}} = \frac{D_{111}}{2.98}$$

Mixing Time min.	$\sum(C' - C'_m)^2$	D_{111}	I_{111}
0.5	0.3040	0.175	0.059
1.5	0.1139	0.108	0.036
2.5	0.00950	0.0314	0.010
4.5	0.00735	0.0276	0.009
7.5	0.00400	0.0204	0.007

Uniformity Index values were calculated by the method just described for each time interval examined. The value of $D_{(1)}^{(v=1 \text{ cc.})}$ was calculated from Equation (2); a bulk density was assumed of 1.30 g./cc. for the dye-dextrose mixture. This latter figure is not the bulk density of the dry dextrose powder (which was about 1.0 g./cc.), but the density of the powder after contact with a small amount of water, and was believed the more correct average value to employ in dealing with kaolinite-water systems.

The mean concentration employed in these calculations was the over-all average value found for all samples, rather than the mean value found from six samples at each time interval. This choice was made because six samples were obviously not enough to yield a statistically reliable mean concentration, although this number was believed adequate to reflect the magnitude of deviations from the mean. In most instances the over-all average concentrations thus found were close to the values calculated from the measured quantities of dextrose and clay used. A representative set of data for one run is shown in Table 1.

From the torque-time curves auto-

matically recorded by the apparatus, the cumulative energy requirements for the mixing process were calculated by graphical integration. The cumulative energy input per unit weight of clay present in the mixture was then calculated, correction being made for the reduction in mill contents accompanying removal of samples for analysis.

Discussion of Results

A. EFFECT OF WATER: CLAY RATIO ON MIXING TORQUE

Results of this study are presented in Table 2 and Figure 6, and show that mixing torque varies in a rather unusual way with increasing water content. Addition of small amounts of water to dry clay is accompanied by a rapid initial increase in torque; at water : clay ratios between 0.10 and 0.20 there is a significant decrease in torque, followed by an extremely large increase, a maximum being reached at a water : clay ratio of about 0.33. Above this water content range, the torque decreases relatively rapidly.

In the lower water content range (water : clay ratio between 0-0.10) the increase in torque appears to be caused by partial pelletizing of the clay; the

pellets formed are of reasonably large size, and are driven by the finger prongs through the bulk of powdered solid. In the water : clay ratio range of 0.10-0.15 the mixture is completely transformed into a mass of small, almost uniform size spherical pellets; these aggregates tend to roll over one another during mixing without much mutual interference. This peculiar condition appears to be responsible for the low mixing torque observed in this water-content range.

As the water content is increased further, the pellets begin to cohere and grow larger until, at the water content corresponding to the maximum torque observed, the mixture is a homogeneous, cohesive, plastic solid. Further increase in water content results in a decrease in shear strength of the paste, with consequent reduction in mixing torque.

It is evident from Figure 6 that, when dextrose (10 g./100 g. of clay) is present, the torque vs. water-content curve is displaced to the left with-

mixing

Table 2.—Mixing Torque vs. Water Content for Kaolinite and Kaolinite-Dextrose Systems

Water Content g./100 g. clay	No Additive		10 g. Dextrose/100 g. Clay	
	Bulk Density g./cc.	Torque mg./g. clay	Bulk Density g./cc.	Torque mg./g. clay
0	1.12	0.04
5	1.28	0.27	1.36	...
10	1.44	0.27	1.58	0.31
15	1.52	0.17	1.77	0.38
20	1.75	0.23	1.91	1.19
25	1.99	0.44	1.88	3.66
30	1.88	1.77	1.85	2.54
35	1.83	3.85	1.74	1.77
40	1.78	2.16	1.73	0.92
45	1.74	1.35	1.74	0.38
50	1.70	0.92	1.68	0.19

Mixer content: 260 g. dry clay.

Table 3.—Density-, Volume-, and Water-Content Relationships for Kaolinite-Water Systems

Water Content g./100 g. clay	Density g./cc.	Pure Kaolinite		Kaolinite + Dextrose 10 g./100 g. clay		
		Vol./100 g. clay, cc.	Vol. Liq./100 g. clay, cc.	Density g./cc.	Vol./100 g. clay, cc.	Vol. Liq./100 g. clay, cc.
0	1.12	89	0	0
5	1.28	82	5	1.36	85	11.3
10	1.44	77	10	1.58	76	17.0
15	1.52	76	15	1.77	68	21.2
20	1.75	69	20	1.91	68	26.2
25	1.99	63	25	1.88	72	31.2
30	1.88	69	30	1.85	76	36.6
35	1.83	74	35	1.74	83	41.1
40	1.78	79	40	1.73	87	46.1
45	1.74	83	45	1.74	89	51.5
50	1.70	89	50	1.68	92	56.1

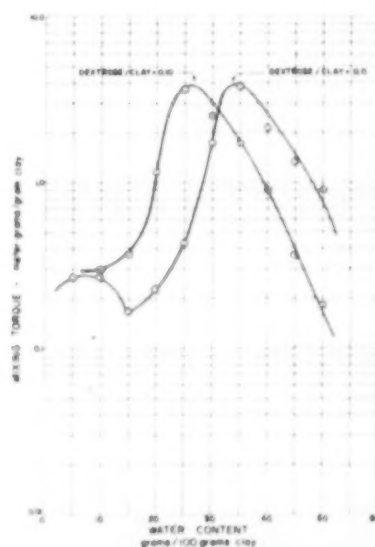


Fig. 6.

increasing the volume of the liquid phase, one gram of dextrose being equivalent to about 0.6 cc. of water. The maximum and minimum torque values observed at low water contents (water:clay ratios between 0.05-0.15) for pure kaolinite do not appear in the presence of dextrose; their absence, however, can probably be explained by the fact that the solution of dextrose in small amounts of water yields a highly viscous liquid which acts as a glue. The adhesive qualities of such a mixture would thus tend to obscure the reduction in torque which results when the mixture becomes pelletized.

It should be pointed out that the explanation offered above for the part played by dextrose in changing the rheological properties of kaolinite-water mixtures patently ignores the effect of adsorption of either water or dextrose by the clay. This simplification is probably not objectionable for a substance such as kaolinite which has an adsorptive capacity well below the quantities of water and/or dextrose present, but certainly could not be justified if the solid under consideration were very highly adsorptive (e.g., active silica) or swelled in the liquid present (e.g., montmorillonite).

B. POWER REQUIREMENTS FOR MIXING SIMPLE WATER-KAOLINITE SYSTEMS

Data showing the dependence of mixer power input upon water content and mixture volume for simple kaolinite-water systems are presented in Table 4, Figures 8 and 9. The torque values observed in these tests differ somewhat from those reported above, because of (a) differences in mixture volume at any given water content, and (b) minor variations in the force applied on the

Lucite piston used to confine the mixture in the mill. Despite these differences, some useful qualitative conclusions can be drawn from these measurements.

In Figure 8, as in Figure 6, it is seen that in the water:clay ratio range of 0.20-0.50, for a fixed mixture volume, the mixing torque (expressed per unit weight of clay present) rises rapidly with increasing water content until a water:clay ratio of about 0.33 is reached. Increasing water content beyond this value is accompanied by a rapid reduction in power input per unit weight of clay. The maximum mixing torque occurs at a water:clay ratio corresponding closely to the plastic limit of the kaolinite used (water:clay ratio = 0.31).

It is interesting to note that, irrespective of water content, the energy input (or torque) per unit weight of clay increases as the volume of the mix is increased within the mixture volume range studied. It is thus evident that the power requirements for mixing solids of this type are not merely proportional to the weight (or volume) of the material being mixed, but increase much more rapidly than this; Figure 9 shows these trends clearly. It should be pointed out also that (within the volume range investigated) the increase in mixing energy with mixture volume is more marked for high water-content systems than for low. Since, for mixture volumes much greater than the capacity of the mill (400 cc.), the power requirements per unit weight of clay must decrease, the curves plotted on Figure 9 must pass through maxima with increasing mixture volume. The fact that the curves for water:clay ratios

of 0.4 and 0.5 level off at the higher mixture volumes suggests that these maxima are being approached for these two systems. The curves for the lower water-content systems (water:clay ratios of 0.2 and 0.3) are concave upward; this indicates that the maximum mixing energy requirements per unit weight of clay occur at mixture volumes considerably larger than those employed. It is, however, virtually impossible to obtain reliable data for larger mixture volumes at these water contents, because the solid tends to be forced out of the mill during mixing, and extremely erratic torque readings are obtained.

In a mill of the type employed for this study, the utilization of mixing energy can be conveniently divided into two categories; one is energy dissipation by simple penetration of the finger prongs into the mass of solid lying beneath the plane through the centers of the shafts; the other is energy dissipation by transport of solid lying above the prongs downward into the lower part of the mill with subsequent extrusion upwards of the lower lying solid. Evidently energy dissipation by this latter mechanism cannot occur if there is insufficient solid present to form a "bank" between the fingers. Thus this observation can explain the relatively rapid rise in mixing torque over a fairly narrow range of mixture volumes. It is significant that, for the four clay-water systems plotted on Figure 9, the breaks in the curves occur roughly between 170 and 200 cc., which is approximately the volumetric capacity of the mill when the mixture level lies at the plane through the horizontal axes of the shafts (i.e., about $\frac{1}{2}$ the full capacity of the mill).

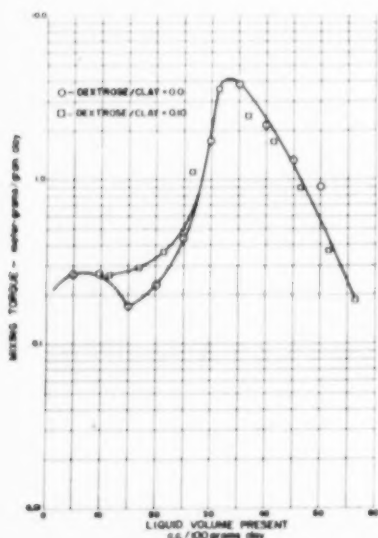


Fig. 7.

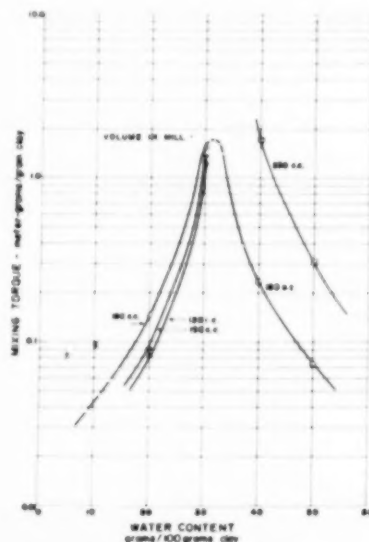


Fig. 8.

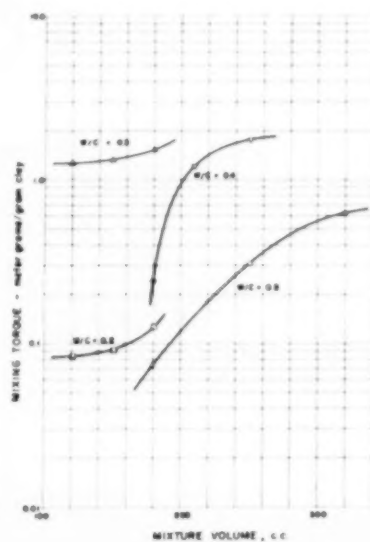


Fig. 9.

If no bank forms between the fingers, then the energy dissipation per unit of clay weight would be expected to be approximately constant with minor variations in mixture volume, since the volumetric clay displacement per revolution of the shafts would be nearly proportional to the volume of mixture present. The power requirements will then largely be determined by the shear strength, and hence water content of the mix. Data of Figures 8 and 9 appear to bear out these hypotheses.

C. EFFECT OF WATER : CLAY RATIO ON MIXING RATE

For the process of mixing dextrose with kaolin-water systems (dextrose : dry clay ratio held constant at 0.10), the variation of the Uniformity Index with time for various water : clay ratios is shown in Table 4 and Figure 10. In these tests, the mixture volume was held constant at 180 cc., or about one-half the total volumetric capacity of the mixer. Several important trends can be observed.

The rate of decrease of Uniformity Index (or rate of attainment of uniformity) for dry clay-

dry dextrose mixtures is rapid. When mixing is carried out at a water : clay ratio of 0.20, the decrease in Uniformity Index is much less rapid. There is also evidence (also verified by other data described below) that at this water content, the peculiar phenomenon of unmixing occurs to a detectable extent. This, as noted above, is believed due to accumulation of dextrose on the surface of clay pellets which remain relatively undisturbed during mechanical mixing, and give rise to regions in the mixture containing abnormally large concentrations of dextrose.

At a water : clay ratio of 0.3, the rate of attainment of uniformity is again rapid indeed, nearly as rapid as the dry-powder mixing process. At still higher water contents, however, the rate of homogenization decreases greatly;

Table 4.—Summarized Table of Data and Calculations
Mixing Characteristics of Kaolinite-Dextrose-Water Systems
(Dextrose Content: 10 g./100 g. clay)

Water Content wt.-%	Dextrose Dry Weight wt.-%	Initial U.I. of Clay + Water g./g.	Initial U.I. of Mixture g./g.	Final U.I. of Mixture g./g.	Approx. % Final U.I. of Mixture	Time before Dextrose Addition sec.	Mixing Time min.	U.I. at End of Mixing	U.I. at End of Settling
0.0	1.00	1.00	1.00	1.00	100	0.00	1.00	1.00	1.00
0.1	0.99	0.99	0.99	0.99	99	0.00	1.00	0.99	0.99
0.2	0.98	0.98	0.98	0.98	98	0.00	1.00	0.98	0.98
0.3	0.97	0.97	0.97	0.97	97	0.00	1.00	0.97	0.97
0.4	0.96	0.96	0.96	0.96	96	0.00	1.00	0.96	0.96
0.5	0.95	0.95	0.95	0.95	95	0.00	1.00	0.95	0.95
0.6	0.94	0.94	0.94	0.94	94	0.00	1.00	0.94	0.94
0.7	0.93	0.93	0.93	0.93	93	0.00	1.00	0.93	0.93
0.8	0.92	0.92	0.92	0.92	92	0.00	1.00	0.92	0.92
0.9	0.91	0.91	0.91	0.91	91	0.00	1.00	0.91	0.91
1.0	0.90	0.90	0.90	0.90	90	0.00	1.00	0.90	0.90
1.1	0.89	0.89	0.89	0.89	89	0.00	1.00	0.89	0.89
1.2	0.88	0.88	0.88	0.88	88	0.00	1.00	0.88	0.88
1.3	0.87	0.87	0.87	0.87	87	0.00	1.00	0.87	0.87
1.4	0.86	0.86	0.86	0.86	86	0.00	1.00	0.86	0.86
1.5	0.85	0.85	0.85	0.85	85	0.00	1.00	0.85	0.85
1.6	0.84	0.84	0.84	0.84	84	0.00	1.00	0.84	0.84
1.7	0.83	0.83	0.83	0.83	83	0.00	1.00	0.83	0.83
1.8	0.82	0.82	0.82	0.82	82	0.00	1.00	0.82	0.82
1.9	0.81	0.81	0.81	0.81	81	0.00	1.00	0.81	0.81
2.0	0.80	0.80	0.80	0.80	80	0.00	1.00	0.80	0.80
2.1	0.79	0.79	0.79	0.79	79	0.00	1.00	0.79	0.79
2.2	0.78	0.78	0.78	0.78	78	0.00	1.00	0.78	0.78
2.3	0.77	0.77	0.77	0.77	77	0.00	1.00	0.77	0.77
2.4	0.76	0.76	0.76	0.76	76	0.00	1.00	0.76	0.76
2.5	0.75	0.75	0.75	0.75	75	0.00	1.00	0.75	0.75
2.6	0.74	0.74	0.74	0.74	74	0.00	1.00	0.74	0.74
2.7	0.73	0.73	0.73	0.73	73	0.00	1.00	0.73	0.73
2.8	0.72	0.72	0.72	0.72	72	0.00	1.00	0.72	0.72
2.9	0.71	0.71	0.71	0.71	71	0.00	1.00	0.71	0.71
3.0	0.70	0.70	0.70	0.70	70	0.00	1.00	0.70	0.70
3.1	0.69	0.69	0.69	0.69	69	0.00	1.00	0.69	0.69
3.2	0.68	0.68	0.68	0.68	68	0.00	1.00	0.68	0.68
3.3	0.67	0.67	0.67	0.67	67	0.00	1.00	0.67	0.67
3.4	0.66	0.66	0.66	0.66	66	0.00	1.00	0.66	0.66
3.5	0.65	0.65	0.65	0.65	65	0.00	1.00	0.65	0.65
3.6	0.64	0.64	0.64	0.64	64	0.00	1.00	0.64	0.64
3.7	0.63	0.63	0.63	0.63	63	0.00	1.00	0.63	0.63
3.8	0.62	0.62	0.62	0.62	62	0.00	1.00	0.62	0.62
3.9	0.61	0.61	0.61	0.61	61	0.00	1.00	0.61	0.61
4.0	0.60	0.60	0.60	0.60	60	0.00	1.00	0.60	0.60
4.1	0.59	0.59	0.59	0.59	59	0.00	1.00	0.59	0.59
4.2	0.58	0.58	0.58	0.58	58	0.00	1.00	0.58	0.58
4.3	0.57	0.57	0.57	0.57	57	0.00	1.00	0.57	0.57
4.4	0.56	0.56	0.56	0.56	56	0.00	1.00	0.56	0.56
4.5	0.55	0.55	0.55	0.55	55	0.00	1.00	0.55	0.55
4.6	0.54	0.54	0.54	0.54	54	0.00	1.00	0.54	0.54
4.7	0.53	0.53	0.53	0.53	53	0.00	1.00	0.53	0.53
4.8	0.52	0.52	0.52	0.52	52	0.00	1.00	0.52	0.52
4.9	0.51	0.51	0.51	0.51	51	0.00	1.00	0.51	0.51
5.0	0.50	0.50	0.50	0.50	50	0.00	1.00	0.50	0.50
5.1	0.49	0.49	0.49	0.49	49	0.00	1.00	0.49	0.49
5.2	0.48	0.48	0.48	0.48	48	0.00	1.00	0.48	0.48
5.3	0.47	0.47	0.47	0.47	47	0.00	1.00	0.47	0.47
5.4	0.46	0.46	0.46	0.46	46	0.00	1.00	0.46	0.46
5.5	0.45	0.45	0.45	0.45	45	0.00	1.00	0.45	0.45
5.6	0.44	0.44	0.44	0.44	44	0.00	1.00	0.44	0.44
5.7	0.43	0.43	0.43	0.43	43	0.00	1.00	0.43	0.43
5.8	0.42	0.42	0.42	0.42	42	0.00	1.00	0.42	0.42
5.9	0.41	0.41	0.41	0.41	41	0.00	1.00	0.41	0.41
6.0	0.40	0.40	0.40	0.40	40	0.00	1.00	0.40	0.40
6.1	0.39	0.39	0.39	0.39	39	0.00	1.00	0.39	0.39
6.2	0.38	0.38	0.38	0.38	38	0.00	1.00	0.38	0.38
6.3	0.37	0.37	0.37	0.37	37	0.00	1.00	0.37	0.37
6.4	0.36	0.36	0.36	0.36	36	0.00	1.00	0.36	0.36
6.5	0.35	0.35	0.35	0.35	35	0.00	1.00	0.35	0.35
6.6	0.34	0.34	0.34	0.34	34	0.00	1.00	0.34	0.34
6.7	0.33	0.33	0.33	0.33	33	0.00	1.00	0.33	0.33
6.8	0.32	0.32	0.32	0.32	32	0.00	1.00	0.32	0.32
6.9	0.31	0.31	0.31	0.31	31	0.00	1.00	0.31	0.31
7.0	0.30	0.30	0.30	0.30	30	0.00	1.00	0.30	0.30
7.1	0.29	0.29	0.29	0.29	29	0.00	1.00	0.29	0.29
7.2	0.28	0.28	0.28	0.28	28	0.00	1.00	0.28	0.28
7.3	0.27	0.27	0.27	0.27	27	0.00	1.00	0.27	0.27
7.4	0.26	0.26	0.26	0.26	26	0.00	1.00	0.26	0.26
7.5	0.25	0.25	0.25	0.25	25	0.00	1.00	0.25	0.25
7.6	0.24	0.24	0.24	0.24	24	0.00	1.00	0.24	0.24
7.7	0.23	0.23	0.23	0.23	23	0.00	1.00	0.23	0.23
7.8	0.22	0.22	0.22	0.22	22	0.00	1.00	0.22	0.22
7.9	0.21	0.21	0.21	0.21	21	0.00	1.00	0.21	0.21
8.0	0.20	0.20	0.20	0.20	20	0.00	1.00	0.20	0.20
8.1	0.19	0.19	0.19	0.19	19	0.00	1.00	0.19	0.19
8.2	0.18	0.18	0.18	0.18	18	0.00	1.00	0.18	0.18
8.3	0.17	0.17	0.17	0.17	17	0.00	1.00	0.17	0.17
8.4	0.16	0.16	0.16	0.16	16	0.00	1.00	0.16	0.16
8.5	0.15	0.15	0.15	0.15	15	0.00	1.00	0.15	0.15
8.6	0.14	0.14	0.14	0.14	14	0.00	1.00	0.14	0.14
8.7	0.13	0.13	0.13	0.13	13	0.00	1.00	0.13	0.13
8.8	0.12	0.12	0.12	0.12	12	0.00	1.00	0.12	0.12
8.9	0.11	0.11	0.11	0.11	11	0.00	1.00	0.11	0.11
9.0	0.10	0.10	0.10	0.10	10	0.00	1.00	0.10	0.10
9.1	0.09	0.09	0.09	0.09	9	0.00	1.00	0.09	0.09
9.2	0.08	0.08	0.08	0.08	8	0.00	1.00	0.08	0.08
9.3	0.07	0.07	0.07	0.07	7	0.00	1.00	0.07	0.07
9.4	0.06	0.06	0.06	0.06	6	0.00	1.00	0.06	0.06
9.5	0.05	0.05	0.05	0.05	5	0.00	1.00	0.05	0.05
9.6	0.04	0.04	0.04	0.04	4	0.00	1.00	0.04	0.04
9.7	0.03	0.03	0.03	0.03	3	0.00	1.00	0.03	0.03
9.8	0.02	0.02	0.02	0.02	2	0.00	1.00	0.02	0.02
9.9	0.01	0.01	0.01	0.01	1	0.00	1.00	0.01	0.01
10.0	0.00	0.00	0.00	0.00	0	0.00	1.00	0.00	0.00

* Based on initial weight of clay, and assuming no solid is removed from the mixer.

** Corrected for sample removal.

mixing

at a water : clay ratio of 0.5, the Uniformity Index is nearly fivefold greater than that at a ratio of 0.3 after any given time of mixing. Although the effect of water content on rate of change of Uniformity Index with time appears to become less marked at the higher water contents studied, there was no evidence of an increase in rate of attainment of uniformity with increasing water : clay ratio except between 0.2 and 0.3.

It is clear from Figure 10 that the Uniformity Index drops precipitously in the first half minute of the mixing process, irrespective of water : clay ratio; the major fraction of the mixing period is spent in reducing I_{11} from about 0.10 to 0.010. The precise nature of the relationship between I_{11} and time is undoubtedly very complex, and no attempt has yet been made to derive this relationship by theoretical methods. It has been observed, however, that plots of I vs. θ on logarithmic coordinates approximate straight lines in the interval $10 > I > 1$, which can be expressed by:

$$I = I_0 e^{n\theta}$$

the exponent n varying between -0.7 and -1.2 . The statistical analysis of mixing developed by Brothman *et al.* (1) predicts that the logarithm of mixture uniformity will be an exponential function of time; the trends of Uniformity Index with time described here are qualitatively in agreement with this prediction. More careful consideration of the nature of the I vs. θ relationship will be taken, however, when more extensive experimental data become available.

Data of Figure 10 thus indicate that most rapid mixing occurs with dry solids, or with a clay-water system in the neighborhood of the plastic limit; at intermediate or higher water contents, the rate of mixing drops off rapidly. Considerably more information is revealed about the character of the mixing process under these conditions by inspection of Figure 11, which shows the variation in I_{11} (values taken from the smoothed curves of Figure 10) with the cumula-

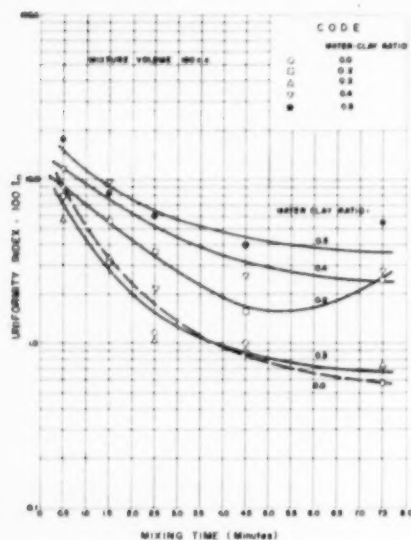


Fig. 10.

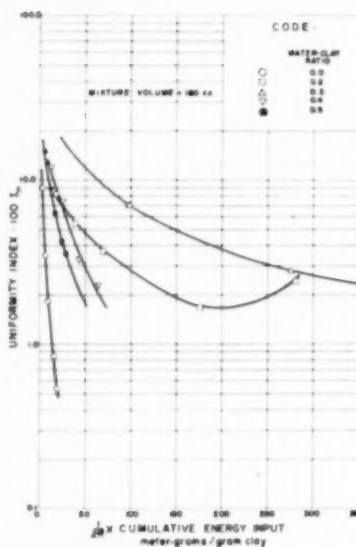


Fig. 11.

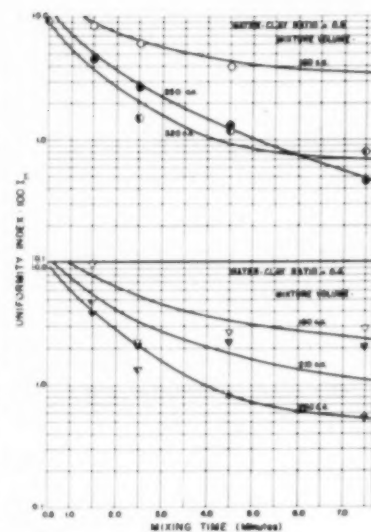


Fig. 12a

tive energy input to the mixture, expressed per unit weight of clay present.

It is clear from this graph that the most efficient utilization of energy (i.e., maximum reduction in $I_{(1)}$ per unit of energy input) occurs with the dry powder mix, whereas least efficient energy utilization occurs with the mixture containing 0.3 g. of water/g. of clay. Thus, in spite of the fact that the time-rate of attainment of mixture uniformity is nearly the same for these two systems, the high cohesiveness of the plastic mixture necessitates an expenditure of energy far in excess of that necessary to achieve mixture uniformity by a simple displacement mechanism. In other words, the difference in energy requirements for these two systems represents wasted energy, or energy expended in shear and not put to direct use in mixing. The fact that the rate of attainment of mixture uniformity in a system with a water:clay ratio of 0.3 is very rapid may thus be regarded as fortuitous; the rapidity of mixing is due solely to the fact that at this water content the rate of energy input to the mix is extraordinarily large.

For higher water-content systems it will be observed that the efficiency of energy utilization approaches with increasing water content that of the dry powder system. This trend could never have been predicted from the $I_{(1)}$ vs. time curves of Figure 10, an observation which illustrates the danger of judging the efficiency of a mixing process merely from the time required for uniformity to be achieved.

As the water:clay ratio increases from 0.0 to 0.3, the efficiency of energy utilization decreases rapidly; this trend, coupled with the observations made regarding the time-rate of attainment of uniformity in this water content region, indicates that this is an unsatisfactory area in which to carry out mixing operations, at least with a mixer such as that employed for this study.

The above evidence makes it clearly necessary to differentiate between ra-

pidity and efficiency of mixing. There are evidently two, and possibly three, sets of conditions under which rapid mixing can be realized; one is a dry powder system; the second is a system in which the major constituents of the mixture are at or near their plastic limit; the third (presumably) is a free-flowing system of high liquid content. There appear to be only two sets of conditions under which mixing energy is most efficiently utilized: one is a dry powder system; the other is a system of high liquid content.

If the two terminal conditions (i.e., no liquid, or high liquid content) are for practical reasons excluded from consideration, then one must choose between a rapid mixing process involving a large power expenditure, or a much slower process requiring far less energy. The decision, therefore, of the proper liquid content at which mixing should be conducted will involve a rather close balance between time and power economy; furthermore, adjustment of liquid content (particularly in the neighborhood of the plastic limit) will of necessity be extremely critical if relatively constant mixing characteristics and power requirements are to be maintained in any continuous mixing operation.

D. EFFECT OF MIXTURE VOLUME

The effects of variation of mixture volume upon the change of Uniformity Index with time, and with the cumulative energy input per unit weight of clay, for clay-water systems of varying water content, are presented in Table 4 and in Figures 12 and 13.

Inspection of Figure 12 shows that, for the two higher water-content sys-

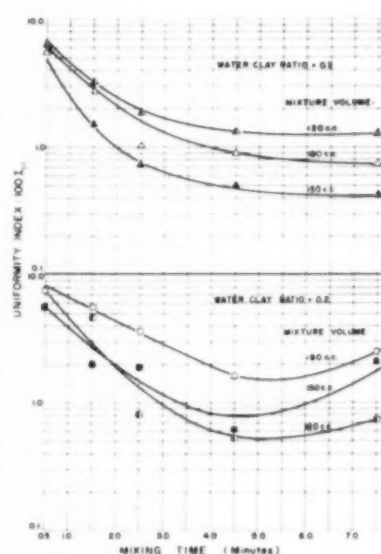


Fig. 12b

tems (water:clay ratio 0.4 and 0.5), increasing the mixture volume increases greatly the rapidity of mixing. The variation of mixing rate with mixture volume appears to be more pronounced at the lower mixture volumes. For the lower water-content systems, however, the rapidity of mixing passes through a maximum as the mixture volume is increased. Of equal importance are the observations that (at all water contents) the effect of mixture volume on rate of attainment of uniformity is greatest during the latter part of the mixing process, and that the influence of mixture volume on mixing rate is more pronounced for the higher water-content systems.

Figure 13, showing the variation in Uniformity Index with cumulative energy input per unit weight of clay, with mixture volume and water content as parameters, provides additional helpful information. It will be observed that, irrespective of water content, an increase in mixture volume is in all cases accompanied by a decrease in efficiency of utilization of energy. The change in efficiency of energy consumption with mixture volume is more abrupt for the lower water-content systems.

The important practical conclusions to be drawn from these data are: (1) there is an optimum mixture volume for each system of given water content

at which most rapid mixing occurs; (2) the maximum efficiency of utilization of mixing energy is achieved at mixture volumes far below this optimum; and (3) at the higher water contents, quite large volumes of solid can be mixed efficiently (in terms of energy consumption) and homogeneity achieved relatively rapidly.

In order to point out more clearly these trends, the time in minutes required for a mixture to reach an arbitrary low Uniformity Index ($I_{11} = 0.03$) has been plotted against mixture volume for various water-content systems, and the energy required per unit weight of clay to accomplish the same result plotted similarly in Figure 14. From Figure 14 it is found that most rapid mixing ($\theta = 0.4$ min.) can be achieved (with the mixer and mill speed) with the use of about 150 cc. of a mixture containing 30 g. of water/100 g. of clay. This will require an energy expenditure of 105 meter g./g.

of clay present. If, however, two minutes can be spent in this mixing process, several alternative systems are possible, as illustrated in Table 5.

Inspection of this table suggests that the most practicable operating condition is probably at a water:clay ratio of 0.5 and a mixture volume of 270 cc. These operating conditions make efficient use of the mill capacity, and at the same time the desired degree of mixing can be accomplished with relatively low energy consumption.

mixing

Results of this study thus lead to a previously unexpected conclusion—although most rapid mixing can be achieved with clay-water systems near the plastic limit, considerably greater utilization of mill capacity, and more efficient use of power can be realized with relatively little sacrifice in mixing speed if higher water content systems are employed.

Correlations of the type presented in Figure 14 can thus prove to be useful in aiding the selection of optimum conditions for performing mixing operations. It should be kept in mind, however, that extrapolation of such data to mixing operations carried out in different-size or different-type apparatus, or with different solid-liquid systems, is open to serious objection. It seems not improbable that the qualitative observations made in this study may be applicable to analogous mixing processes, but quantitative prediction of the characteristics of mixing operations in general will necessitate much more experimental work of the type described herein.

Table 5.

For $\theta = 2.0$ min. ($I_{11} = 0.03$)

Water-Kaolinite Ratio	Mixture Volume, cc.	Wt. of Clay in Mill, g.	Energy Expended meter-g./g. clay $\left(\times \frac{1}{2\pi}\right)$	Total Energy Expended meter-g. $\left(\times \frac{1}{2\pi}\right)$
0.20	110	164	12	1,970
	170	233	60	15,200
0.30	112	163	85	13,900
	190	276	300	83,000
0.40	230	295	70	20,600
	280	359	110	39,500
0.50	270	300	40	12,000
	350	389	55	21,400

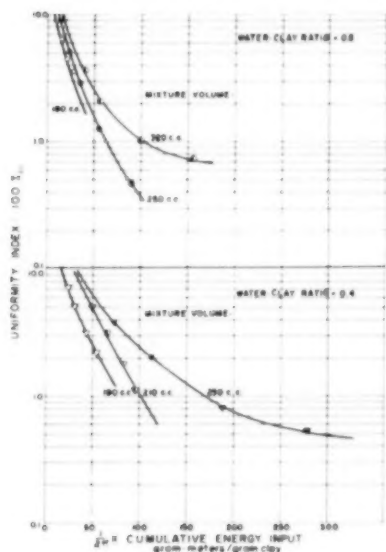


Fig. 13a

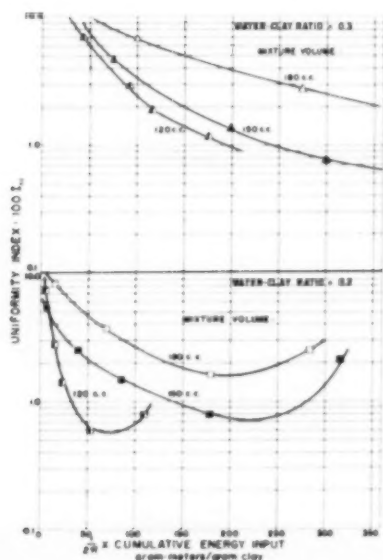


Fig. 13b

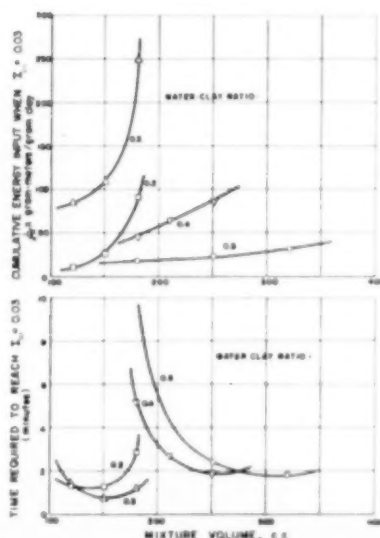


Fig. 14.

E. EXPERIMENTAL ACCURACY

One complication arises in the experimental procedure employed in this study which undoubtedly reflects upon the accuracy of the quantitative results described. This is the gradual reduction in mixture volume which resulted from removal of samples for analysis, since thirty 1-cc. samples were removed from each batch during each mixing run. The reduction in volume due to sampling is to some extent counteracted by an increase in volume caused by solution of dextrose in the clay-water mixtures (see Table 4). When the initial mixture volume was small, however, the loss nevertheless represented an appreciable fraction of the total. The effect of this volume reduction on time-rate of attainment of mixture uniformity is probably small, since the major changes in Uniformity Index occur early in the mixing process when the reduction in volume by sampling is small. It is likely that, if the mixing operations had been carried out at constant volume, the Uniformity Index vs. time curves (for the higher water-content systems) would have been somewhat steeper during the latter part of each mixing period. The basis for this conclusion is the observation that, for the higher water content systems, reduction in mixture volume decreases the rate of attainment of uniformity, though such a change has relatively little effect upon the lower water-content systems. By similar analysis, it could be predicted that the Uniformity Index vs. energy curves for constant volume systems would be somewhat less steep (near the end of the mixing period) than for the variable volume systems studied. It seems doubtful, however, that the differences in results brought about by the sampling technique employed could alter significantly the trends or interpretations presented.

The cumulative experimental error in the reported Uniformity Indices is composed of (a) errors of precision and accuracy of sampling, and (b) errors in precision and accuracy of measuring picric acid concentration in the samples. The latter source of error is believed to be minor, since colorimeter readings of duplicate samples of the same solutions were found to be reproducible to within 0.1%. Sampling errors could arise from variations in sample volume, and from variations in density of the sample caused mainly by inclusion of air bubbles. The calibrated sampling syringe was estimated to have a volumetric accuracy of about 0.2%. To minimize errors due to density variations, each sample was packed carefully into the syringe, transferred to a vial, and weighed on an analytical balance. It was found that the average density

variation for a given series of six samples was less than 2%, and the maximum variation seldom exceeded 5%. Assuming these variations to be caused completely by sampling error (which is conservative, since some density variation is attributable to differences in dextrose content), this would lead to a probable error of 0.004 units in the Uniformity Index. This error is less than, but in some cases nearly equal to, the lowest values of $I_{(1)}$, reported in this study. It is clear therefore that the analysis of mixtures more nearly homogeneous than those studied in this work cannot be undertaken without marked improvement in sampling technique.

Although no duplicate runs were made in the course of this study, similar data recently obtained indicate that reproducibility of results is of the order of $\pm 15\%$. This variation is considerably greater than that ascribable to errors in precision and accuracy alone, and is believed caused by minor variations in placement of the dextrose in the mixer at the start of a run, or in the initial distribution of clay in the mixing chamber.

In spite of these limitations the procedure described in this work is readily adaptable to a large number of problems in mixing, and is likely to lead to improved understanding of the kinetics and mechanics of mixing processes.

Conclusions

Results of this work lead to the following conclusions:

1. The formulation of a Uniformity Index to characterize the degree of homogeneity in a solid-liquid mixture, and employment of a colorimetric method of analysis for determination of mixture composition have led to a reliable and reproducible method of analyzing the variables affecting the attainment of homogeneity in mechanical mixing processes.
2. For the process of mixing dextrose with kaolinite-water systems in a simple finger-prong mixer, it has been found that rapid mixing occurs when no water is present, and when the water : clay ratio is in the neighborhood of 0.30. The latter water content is close to the plastic limit of the kaolinite studied. At intermediate or higher water contents, the rate of attainment of homogeneity is much lower. The efficiency of utilization of energy in mixing is highest when no water is present, and is also high at water : clay ratios much greater than 0.30. Energy efficiency is at a minimum at a water : clay ratio in the neighborhood of 0.30.

3. For each clay system of a given water content, there is an optimum mixture volume at which most rapid mixing occurs. Efficiency of mixing energy utilization decreases rapidly as mixture volume is increased above some low value.
4. Although most rapid mixing can be achieved at a water : clay ratio of 0.30, most efficient use of mixing energy and mixer capacity can be made using solids at higher water contents, without great sacrifice in rapidity of mixing.

Acknowledgment

This study was conducted in the M.I.T. Soil Stabilization Laboratory under the sponsorship of the Research and Development Laboratories, Corps of Engineers, U. S. Army. Thanks are due to Messrs. V. H. Rodes and J. H. Reynolds of E.R.D.L., and to Dr. T. W. Lambe and Dr. R. T. Martin of M.I.T., for their technical assistance.

Notation

C_A = volume concentration of component A in a random sample of mixture, cc.A/cc. mix

C_A^m = average volume concentration of component A in mixture, cc.A/cc. mix

C' = picric acid concentration, mg./cc. mixture

C'^m = average picric acid concentration, mg./cc. mixture

D_v = fractional root-mean-square deviation of volume concentration of component A in random samples of mixture, each sample of constant volume v (dimensionless)

D_v^0 = value of D_v when no mixing has taken place

$D_{(1)}$ = value of D_v for $v = 1.0$ cc.

$D_{(1)}^0$ = value of D_v^0 for $v = 1.0$ cc.

I_v = Uniformity Index based on samples of volume v

$I_{(1)}$ = Uniformity Index based on samples of volume = 1.0 cc.

n = number of samples

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Presented at A.I.Ch.E. San Francisco meeting.

helical coil heat transfer in mixing vessels

J. Y. Oldshue and A. T. Gretton

Mixing Equipment Company, Inc., Rochester, New York

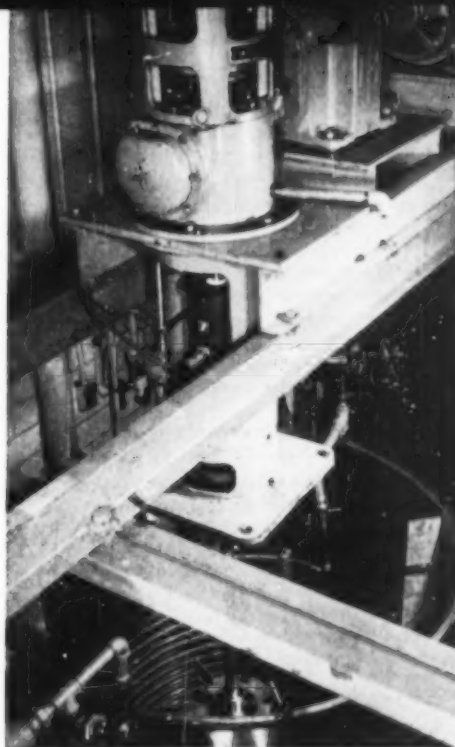


Fig. 8. Photograph of experimental equipment.

Heat-transfer coefficients for helical coils in a mixing vessel were measured with the use of flat-blade turbine impellers. Data were obtained for baffled conditions. The power consumption of the impeller was measured using a strain-gauge torque-meter. A correlation of heating and cooling data was effected by a graphical method.

A Reynolds number range of 400 to 1,500,000 was used. Among the variables investigated were impeller speed, power, ratio of impeller size to tank size, baffle position and tube diameter.

Heat transfer is a common auxiliary process requirement in mixing applications.

Common types of heat-transfer surfaces are helical coils, jackets, and vertical tubes. Heat-transfer data were recently published (3) for a vertical tube system in which the vertical tubes served both as baffles and as heat-transfer surfaces. Previously available data (1, 2) on helical-coil installations covered operation in unbaffled tanks. A summary of prior work on heat transfer (6) also presents basic flow patterns and the reasons for the use of baffles in a mixing vessel.

Equipment and Procedure—Summary

Flat-blade turbines, 12, 16, 20, 24 and 28 in. in diam., illustrated in Figure 1, were used throughout this work. Fluid viscosities ranging from 0.4 to 400 centipoises, and Reynolds numbers ranging from 400 to 1,500,000, were investigated.

The tank was 48 in. in diam., with a 48-in. liquid level. Coils were arranged for both steady- and unsteady-state operation. The copper

tubes used were 3/4 in. O.D. and the stainless-steel tubes also used were 1 1/4 in. O.D. Figure 2 shows the arrangement of the equipment.

Thermocouples were imbedded in the tube wall; thus an experimental temperature difference across the fluid film was given.

Experimental Results

GENERAL CORRELATION OF h_c

The general correlation of h_c with other variables is given as

$$\frac{h_c d}{k} = 0.17 \left(\frac{ND^2 \rho}{\mu} \right)^{0.67} \left(\frac{C_p \mu}{k} \right)^{0.37} \left(\frac{D}{T} \right)^{0.1} \left(\frac{d}{T} \right)^{0.5} \quad (1)^*$$

Experimental conditions used to determine Equation (1) are given in the

* Terms in Equation (1) are given in Notation and plotted in Figure 3.

For Tables 1, 2, 3, 4, and 6, order document 4411 from A.D.I. Auxiliary Publications Photoduplication Service, Library of Congress, Washington 25, D. C., remitting \$1.25 for microfilm or \$1.25 for photoprints.

report. The range of application is recommended as:

Tank size: All sizes.

Relations have been shown to hold by Rushton and Dunlap (3).

Baffles: Either on wall or inside coil.

Tube diameter: $0.018 \leq d/T \leq 0.036$.

Viscosity: Experimental data up to 400 centipoises.

Data of Uhl (7) indicate that these relations should hold into the viscous range, 10,000 centipoises.

Tube spacing: See report.

Turbine type: Flat-blade turbine.

HEATING AND COOLING

A 16-in. diam. flat-blade turbine is placed 16 in. off bottom in a 48-in. diam. tank equipped with helical coils. The coils have a tube diameter of 1.75 in. O.D. and a two-tube diameter spacing (Data are shown in Table I). On this table following the run number the letter (S) is used for steady state and (U) for unsteady state.

The variable of film temperature was studied by obtaining two coefficients, one heating [h_h], and one cooling [h_c], for each condition. The relation used for correlation is given by Equation (2)

$$h_c/h_h = h_o[\mu_s/\mu]^{-m} \quad (2)$$

The surface temperature of the coil was calculated and the ratio of μ_s/μ obtained, where μ_s is the viscosity at the surface temperature, and μ is the bulk viscosity. A plot was made for each condition of h_o and h_h vs. μ_s/μ , on a logarithmic plot, and a straight line drawn in connecting the points. Typical curves are shown on Figure 4. It should be noted on Figure 4 that the slope of the lines (m) is not constant under varying conditions. Two possible causes are:

- (1) The value of (m) is a function of fluid properties such as μ , k and C_p , and
- (2) The value of (m) is dependent upon the value of μ_s/μ and thus on the heat flux through the film.

A plot of (m) vs. viscosity (Cause 1), is shown in Figure 5 for fluid viscosities. The stainless steel tubes and the copper tubes give slightly different results. The spread of the viscosity ratio

μ_s/μ was greater for the small copper tubes, but was not sufficient to enable a correlation with μ_s/μ definitely to prove Cause 2.

An average line was drawn through the points on Figure 5 and is of sufficient accuracy for normal tube proportions and viscosities in industrial use.

For all succeeding correlations the variable of average film temperature was eliminated by making a plot of h_o and h_h vs. μ_s/μ . A straight line was drawn joining the points, picking off the value of h at $\mu_s/\mu = 1.0$. This value of h is termed h_o .

PRANDTL NUMBER

A plot of $h_o d/k$, the Nusselt number, vs. Reynolds number for three different fluid conditions is shown in Figure 6. By cross-plotting these data at constant Reynolds number as a function of Prandtl number, an exponent on the Prandtl number of 0.37 was obtained.

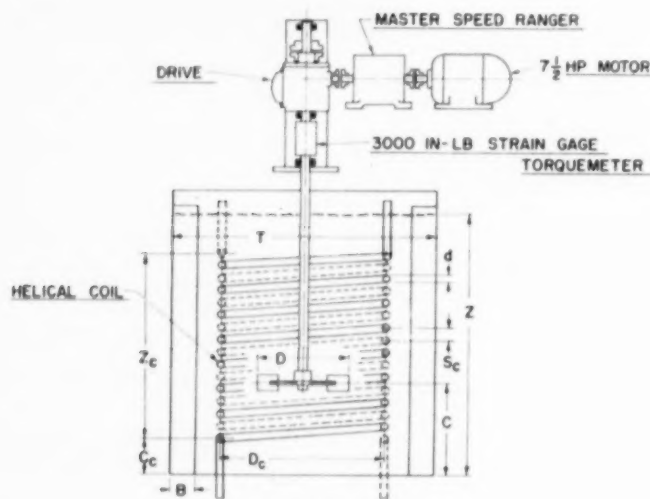
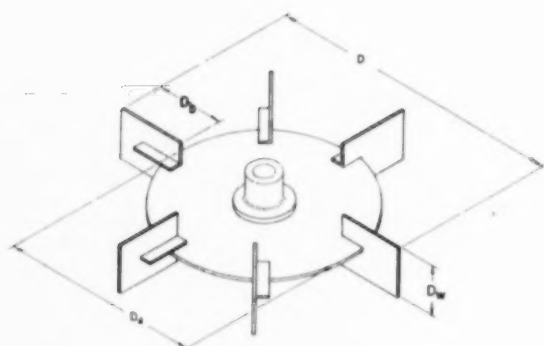


Fig. 2. Experimental equipment.



$$D : D_b : D_w : D_s = 1 : \frac{1}{4} : \frac{1}{8} : \frac{1}{4}$$

Fig. 1. Flat blade turbine impeller.

This agrees with previous data on heat-transfer coefficients.

D/T RATIO

The ratio of impeller diameter (D) to tank diameter (T) was varied between 0.25 and 0.58. Table 2 gives the data used to determine the effect of D/T ratio. In plotting this data at constant Reynolds number, one found the exponent to be 0.1.

TUBE DIAMETER

Data given in Tables 1 and 2 were all for a tube with an O.D. (d) of 1.75 in., and tube spacing [S_c] of 3.5 in. Runs made with a tube diameter of 0.875 in., $S_c = 1.75$, gave the data listed in Table 3. Since the tube diameters used are about as large and as small as would be practical, it is assumed that it is sufficiently accurate to use an exponential relationship even though there are only two different tube sizes. Data from Tables 1, 2 and 3 were plotted at constant Reynolds number and gave an exponent of 0.5 on the d/T ratio.

The use of an exponential relation even though only two points are available is justified by an analogy to data on heat transfer to tubes in other heat exchangers.

TUBE SPACING

The spacing was varied between two diameters and four diameters for the 1.75-in. diam. tube. Table 4 includes additional data for the wide tube spacing. Table 5 shows that a wider tube spacing gives a lower coefficient, and this is more marked in the case of the high viscosity fluid. Table 5 serves as a guide in estimating the effect of tube spacing.

BAFFLE PLACEMENT

Baffles were placed at the tank wall,

Table 5.—Effect of Coil Spacing on Heat Transfer

Tank—48-in. diam., 48-in. liq. level, flat bottom. 365 gal. Four 4-in. wide baffles at the wall.

Impeller—16-in. diam. 6 flat blade turbine, $C = 16$ in.

Coil—1.75-in. O.D.; stainless steel tube; $d_s = 34.25$, S_c , variable.

Fluid	Viscosity	$[h_o]_{S_c = 64}$
		$[h_o]_{S_c = 24}$
Water	0.4 centipoises	0.96
Oil	50 centipoises	0.88

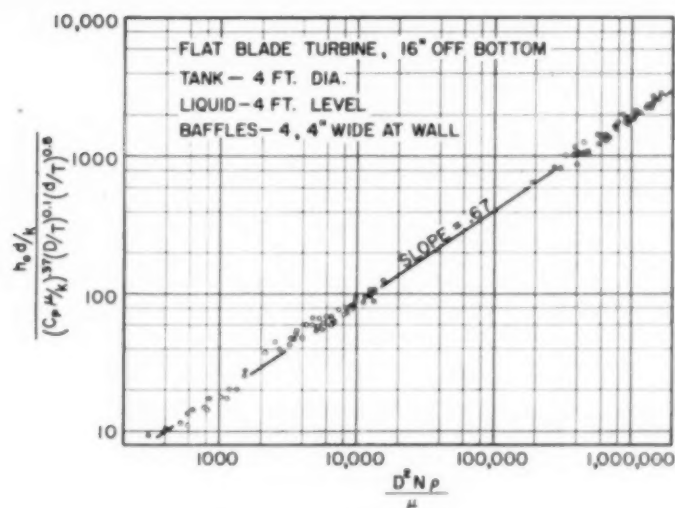


Fig. 3. Overall correlation of h_o .

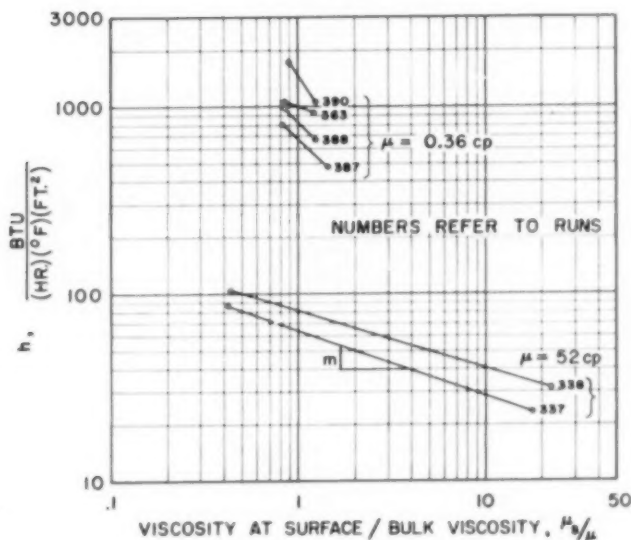


Fig. 4. Evaluation of h_o and m .

1 in. off the wall, and inside the coil (data given in Table 6). It was found that wherever baffles were placed—either at the tank wall or inside the coil—little difference resulted in the heat-transfer coefficient (see Table 7). The important point was that baffle placement can be determined by other process or mechanical requirements and can still achieve good heat transfer.

Power Measurement

In the consideration of a mixing process from a standpoint of fluid mechanics, it is desirable to have a comparison on the basis of equal energy input to the system. Power (energy per unit time) produces an impeller flow and an impeller head. The effect of the ratio of flow to head can be evaluated

best by examining certain of the variables at constant power input. In addition, power is a major item in the cost

Table 7.—Effect of Baffle Placement on Heat Transfer

Tank—48-in. diam., 48-in. liq. level, flat bottom, 365 gal. Four 4-in. wide baffles at the wall.	
Impeller—16-in. diam. 6 flat blade turbine, $C = 16$ in.	
Coil—1.75-in. O.D., stainless steel tube, $D_c = 34.25$, $S_c = 3.5$ in.	
Baffle position	Relative h_o
At wall	1.0
1 in. off wall	.95
Inside coil	.95

of the mixer, and comparison at constant power input yields data on the most effective conditions.

Data presented here extend data (5) for tanks with helical coils, and various baffle conditions. Data are shown in Table 8 which give the value of the power number, $Pg/\rho N^3 D^5$, where P is power, g is gravitational constant over the range of Reynolds numbers of 10^4 and higher, which is the turbulent area.

mixing

Further refinements of data (5) have been possible due to use of the strain-gauge torque-meter measuring technique. Also, the baffles used here are one-twelfth the tank diameter in width rather than one-tenth as used by Rushton (5).

It is seen from Table 8 that with baffles at the wall, the diameter and the spacing of the tubes have no effect on power consumption at constant speed and diameter. Placing the baffles 1 in. off the tank wall, or inside the coils, lowers the power consumption.

COMMENT

Correlations given in Equation (1) are in terms of dimensionless groups, with speed and diameter as the two independent variables to specify mixer

Table 8.—Effect of Baffles and Coils on Impeller Power Consumption

Tank—48-in. diam., 48-in. liq. level, flat bottom, 365 gal.

Impeller—16-in. diam., 6 flat blade turbine, $C = 16$ in.

Coil—1.75-in. O.D., stainless steel tube, $D_c = 34.25$ in., $S_c = 3.5$ in.

Coil	Baffles	N_p at $N_{Re} > 10^4$	Ratio
Tube diam.	Tube spacing position		
0	0 at wall	5.4	1.0
1.75	3.5 at wall	5.2	.96
1.75	7.0 at wall	5.2	.96
1.75	3.5 1 in. off wall	4.8	.89
1.75	3.5 inside coil	4.5	.83
1.75	3.5 no baffles	1.9 [at $N_{Re} = 10^4$]	.35
0.875	1.75 at wall	5.2	.96

characteristics. It is desirable, however, to give a useful comparison of process results maintaining equal power input to the system.

h_o VS. POWER

Since the heat-transfer coefficient varies with (Reynolds number)^{0.67}, h_o varies with [Horsepower]^{0.22} in the turbulent region above a Reynolds number of 10⁴. The exponent is lower than 0.22 in the transition range for Reynolds numbers from 10,000 to 400.

TUBE DIAMETER

In comparing the effect of tube diameter, one finds that the actual tube diameter is commonly used in the Nusselt number. This has caused a problem in comparing heat-transfer data from various sources. The fact that a given coil has a large diameter usually gives a larger value of the Nusselt number regardless of whether a higher heat-transfer coefficient has or has not been obtained.

The relationship given in Equation (1) shows that at constant speed, turbine diameter, and power, since variations in tube diameter do not affect power consumption.

$$h \propto 1/(d)^{0.5} \quad (3)$$

The minimum tube diameter is determined thus by pressure drop through the coil to affect flow of steam or other fluids, or by the minimum spacing between the tubes that can be used without affecting other requirements in the mixing process.

The relationship above is in general agreement with relationships on heat-transfer coefficients in pipes.

FLOW-HEAD RATIO

Power input to a mixing impeller produces an impeller flow and an impeller head. The impeller head is used primarily to generate turbulence in the discharge stream from the impeller. In heat transfer, flow from the impeller passing around the heat-transfer surfaces is the primary source of turbulence.

It has been shown (6) that a large-diameter impeller running at slow speeds gives more flow and lower head than does a small-diameter, high-speed impeller.

The effect of D/T ratio at a constant power input is shown in Figure 7. This indicates that the larger the diameter of the impeller, the higher the heat-transfer coefficient. Heat transfer is aided by large impeller flows. The slope of the line for water is greater than it is for the oil. This is due to the fact that when oil is used, the Reynolds

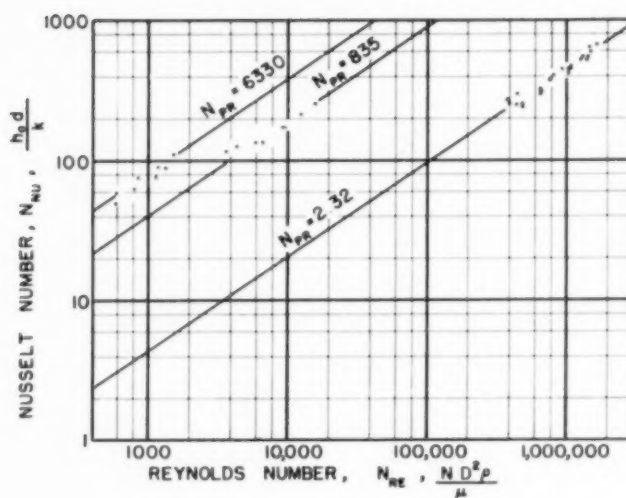


Fig. 6. Nusselt number as a function of Reynolds number.

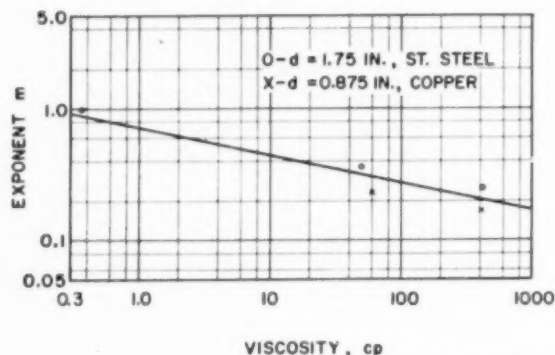


Fig. 5. Value of exponent [m] as a function of bulk fluid viscosity.

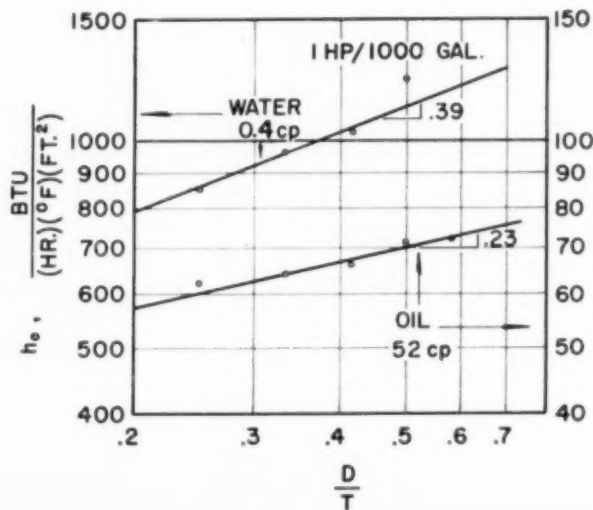


Fig. 7. Effect of D/T ratio at constant power.

number is in the transition region where the power number (N_p) is not constant with N_{Re} .

Comparison with Previous Data

Comparing the results of this investigation with the results of other investigators, it is misleading to use the Nusselt-Reynolds number correlation alone. It has been pointed out previously that investigators using a larger tube diameter come out automatically with a higher Nusselt number at the same Reynolds number. Also an investigator using an impeller which consumes more power at a given Reynolds number due to a difference in design would give a higher heat-transfer coefficient, due primarily to the higher power input.

If power data are available, comparison can be made for each case by considering the operation on the basis of heat-transfer coefficient obtained as a function of energy input to the system.

VERTICAL TUBES

Certain data (3) show that at a Reynolds number equal to 10^6 , $C/T = 1/3$ (optimum impeller position), Prandtl number = 2.32 (water), $D/T = 1/3$, B (number of baffles) = 6, $d = 1.9$ in., $k = 0.39$ B.t.u./(hr.) (sq.ft.) ($^{\circ}$ F./ft.)

$$h_o = (700)(2.32)^{0.3}(D/T)^{0.33}(2/B)^{0.2} \left[\frac{0.39 \times 12}{1.9} \right]$$

$$h_o = 1230$$

For helical coils at Reynolds number equal to 10^6 ,

$$C/T = 1/3,$$

$$\text{Prandtl number} = 2.32, D/T = 1/3, d = 1.75, k = 0.39$$

$$h_o = 1210$$

$$h_o = 1160 \text{ at } d = 1.9 \text{ in.}$$

At the same speed and diameter the power consumption of an impeller in a tank with vertical tubes is 75% of that in a tank with standard wall baffles. On the basis of constant power input, the ratio of coefficients in a tank equipped with vertical tubes to the coefficient in a tank equipped with helical coils is given by

$$\frac{h_o(V.T.)}{h_o(H.C.)} = \frac{1230 \left(\frac{1}{0.75} \right)^{0.22}}{1160} = 1.13 \quad (6)$$

In normal installations the parallel flow of liquids in vertical tubes gives a lower inside coefficient than for a helical coil, and over-all coefficients are usually quite similar. More area can usually be obtained by helical coils than with vertical

tubes. The final choice of vertical tubes or helical coils should normally be made on the basis of economics, ease of installation, replacement, and required heat-transfer surface area.

OTHER DATA ON HELICAL COILS

The estimation of power consumption in unbaffled tanks with impellers that are not similar to impellers of known characteristics can not be made accurately. The industrial use of unbaffled tanks is quite limited and an accurate detailed comparison is not feasible or necessary.

HELICAL COILS VS. JACKETED TANKS

The major source of data for these two systems is (1, 2). When one compares the data on jacketed tanks and helical coils with d/T equal to 0.042, it is found that a jacketed tank at the same Reynolds number and, therefore, at the same power input, has a coefficient about 65% of that obtained with a helical coil. This would vary with the size of tube diameter in the coil. There is some question whether this holds true in baffled vessels. This gives an approximate figure to use, however, in estimating data for jacketed tanks from data available for helical coils.

Experimental Equipment—Details

VESSEL

The vessel was a 48-in. cylindrical tank with a flat bottom. The total height was 56 in. Liquid depth was 48 in. Four 4-in. baffles were used, and bracket arranged so that they might be placed at the tank wall, 1 in. off the tank wall, or inside the helical coil. Figure 8 shows a photograph of the equipment.

FLUIDS

Two fluids were used: Rochester (N.Y.) city water passed through an ion exchanger, and Gulf Crown E turbine oil. The physical properties of the oil are given in Table 9 and the properties of

Table 9.—Properties of Gulf Crown E Turbine Oil

		$^{\circ}$ F.
Specific gravity	100	.885
	130	.874
	210	.844
Viscosity centipoises	100	670
	130	245
	210	35.5
Specific heat, B.t.u./[(lb.)($^{\circ}$ F.)]	100	0.457
	140	0.494
	220	0.513
Thermal conductivity, (B.t.u.)/(hr.) (sq.ft.) ($^{\circ}$ F./ft.)	60	0.90
	150	0.87
	212	0.86

water and tube metals were obtained from Perry (4). The viscosity of the oil was checked in the laboratory over the entire series of experiments and did not vary from the data supplied by the Gulf Refining Co.

COILS

To obtain steady-state conditions, combination coils were used having alternate turns for heating and cooling. The coils were wound on the same outside diameter, and each coil wound with a double pitch. The arrangements of these coils are shown in Figure 2.

Two different tube diameters were used. The essential dimensions of these coils are:

$d = 7/8$ in.	$1 1/4$ in.
$D_o = 35.125$	34.25
$D_o = 36.0$	36.0
$Z_o = 31.5$	31.5
$C_o = 7.0$	7.0
$S_o = 1 1/4$	$3 1/2, 7$

For certain data it was convenient to use a single coil, for either heating or cooling, and to use a suitable unsteady-state calculation to obtain equipment performance at the given condition.

To obtain accurate temperature measurements across the fluid film, copper-constantan thermocouples were im-

mixing

bedded in the tube wall. A circumferential groove 0.037 in. deep was made at the desired thermocouple location (3). The wire thickness was 0.018 in., leaving an average thermocouple junction depth of 0.028 in. The thermocouple wires were joined in a lap joint, $3/4$ in. long, and soft soldered.

Thermocouple leads with Fiberglas insulation were wrapped around the remaining portion of the groove and taken off the opposite side of the tube. The groove was filled with Glyptol cement, and smoothed to avoid disrupting the flow pattern. The wires were brought over to the tank wall and up through the liquid surface.

In a baffled vessel all parts of the helical coil are not subject to the same direction of flow since the direction of flow varies with height of the coil and proximity to the baffles. To insure a valid average temperature, several thermocouple positions were used in tests. Two basic configurations were used:

A. Eleven thermocouples on the heating coil, eleven thermocouples on the cooling coil.

Five thermocouples were spaced equally in a vertical plane, placed on the inside position on

the tube circumference. One set was placed on a radius coinciding with a baffle, and another set was placed between two baffles. The set at the baffle had an additional thermocouple on the top turn mounted on the outside position on the tube circumference.

B₂. Ten thermocouples on one coil (B₁), six thermocouples on the other coil (B₂).

B₃. Five thermocouples were spaced in a vertical plane, one set on a radius coinciding with a baffle, and the other set between two baffles. The ten thermocouples were arranged in a random pattern among outside, inside, top and bottom positions on the tube circumference.

B₄. Three thermocouples were spaced equally in a vertical plane, one set on a radius coinciding with a baffle, another set between two baffles. These were arranged in a random pattern among inside, outside, top and bottom positions on the tube circumference.

Thermocouples were connected to a Brown 16-channel multipoint recorder.

IMPELLERS

Flat-blade turbine impellers with six blades were used, having proportions shown in Figure 1. The diameters used were 12, 16, 20, 24 and 28 in.

POWER MEASUREMENTS

A Baldwin electric resistance strain-gauge torque meter, 3,000 in.-lb. capacity, measured the torque in the mixer shaft. This gave a continuous record on a Brown single-channel strip-chart recorder. A hand tachometer was used to measure the speed.

The drive consisted of a 7½ hp., 1750 rev./min. motor; a variable-speed Master Speedranger, giving a speed variation of three to one upward and downward; and an E Series drive having gear ratios from 6.3 to 26.0.

OTHER MEASUREMENTS

The flow of water through the system was measured with a Fisher and Porter flowrator. The temperature of the water flowing in and out of the cooling coil was measured by mercury in glass thermometers mounted in pipe tees. Steam input was controlled by a pressure regulator, and the amount of condensate weighed on a Toledo scale. The temperature of the fluid in the tank was measured with a thermocouple probe, and with a mercury in glass thermometer.

Procedure

STEADY STATE

The mixer was turned on and set at the desired operating speed. Steam in

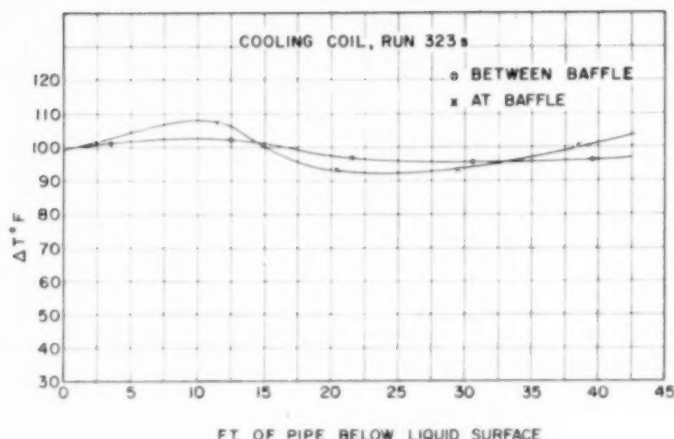


Fig. 9. Graphical integration of mean ΔT .

the heating coil, and cold water in the cooling coil were turned on, and when the tank contents reached an equilibrium temperature, a thirty minute run was made measuring flow rates and temperatures. At least three readings were taken of each measurement.

UNSTEADY STATE

In certain runs only one coil was used for either heating or cooling. These runs were started at 10 to 20°F. from the desired tank fluid temperature, and ended at the same temperature difference above or below the desired temperature. Time of measurements was recorded by the use of a stop watch.

For those unsteady state runs in which $S_c = 3\frac{1}{2}$ in., the second coil remained in the tank but inactive as to heating

or cooling. For the runs in which $S_c = 7$ in., this inactive coil was removed and the single remaining coil was used for either heating or cooling.

Calculation

The lowest power input used, except for natural convection data, was 0.1 hp./1,000 gal. A thermocouple probe indicated that the temperature of the fluid in the vessel was uniform throughout, including the fluid between the tubes of the coil. A constant fluid temperature was used, measured by a mercury in glass thermometer. To obtain natural convection coefficients, the mixer was turned off, and the thermocouple probe was used to get an average temperature reading throughout the entire tank.

Table 10.—Thermocouple Temperature Data for Cooling Water Coil †

Thermocouple position in tank	Thermocouple No.	Thermocouple reading ° F.	Tank temp. ° F.	ΔT ° F.	Length of tubing below liq. surface at thermocouple location ft.
Between baffles	12	93.8	190	96.2	39.6
	13	94.5		95.5	30.6
	14	93.5		96.5	21.5
	15	88		102	12.5
	16	89		101	3.5
	17	89.7		100.3	3.5
	18	90		100	38.5
At baffle	19	96.7	190	93.3	29.5
	20	96.7		93.3	20.4
	21	83		107	11.4
	22	88.7		101.3	2.4

† Run 323.

STEADY STATE

During the steady-state runs, conditions did not vary with time and Equations (4) and (5) represent the method of calculating the mean heat-transfer coefficient over the length of the tube.

h = mean fluid film heat-transfer coefficient over length of tube

Q = heat transferred

c = circumference of tube

L = length of tube

ΔT = temperature driving force between thermocouple position and bulk of fluid at a point

T_m = mean temperature at the thermocouple position over the length of the coil, determined by arithmetic average

T_b = temperature of bulk of the tank fluid

ΔT_m = difference between T_b and T_m

U_m = mean heat-transfer coefficient over entire length of tube, including tube wall resistance

R = resistance of tube wall between thermocouple positions and tube surface

$$Q = U_m c \int_0^L \Delta T dl = U_m c \Delta T_m \quad (4)$$

$$h = \frac{U_m}{[1 - RU_m]} \quad (5)$$

Under duplicate conditions, values of h for heating and cooling were calculated from

$$\int_0^L \Delta T dl$$

obtained graphically as shown in Figure 9, and also by the use of ΔT_m calculated as the difference between T_b and the arithmetic average of the thermocouple readings. The heat-transfer coefficients agreed to $\pm 0.7\%$ in all cases tested, and further calculations were all made from arithmetic averages of the thermocouple temperature readings. Table 10 shows the thermocouple readings used in Figure 9.

UNSTEADY STATE

In certain runs only one coil heating or cooling was used. The experimental procedure was to run the test over a given temperature interval, exactly bracketing the desired fluid temperature. Initially, data from all readings were plotted as a function of time. The measurements were interpolated to coincide with the desired fluid temperature.

A calculation also was made averaging arithmetically the values of all the variables recorded at regular increments of

time over the time interval, and the results were identical, $\pm 2\%$, with that given in the previous procedure. All succeeding calculations were made averaging all measurements over the time interval.

COMPARISON BETWEEN UNSTEADY AND STEADY STATE

Duplicate runs made with both steady-state and unsteady-state conditions give excellent agreement between results. Unsteady-state runs are included in Figure 3 and lie within the correlation.

The same heat-transfer coefficients were obtained in steady-state runs where alternate coils were heating and cooling as were obtained in unsteady-state runs in which adjacent coils were both heating and cooling.

Notation

B = width of baffles

C = impeller distance off tank bottom (measured to horizontal centerline of impeller)

C_c = coil distance from bottom of tank

C_p = specific heat

c = circumference of tube

D = impeller diameter

D_b = length of impeller blade for interrupted blade

D_c = diameter of coil at tube centers

D_d = disk diameter

D_o = outside diameter of coils

D_w = blade width

d = tube diameter

g = gravitational acceleration

h_c = mean cooling coefficient, B.t.u./[(hr.) (° F.) (sq.ft.)]

h_h = mean heating coefficient, B.t.u./[(hr.) (° F.) (sq.ft.)]

h_o = mean heat-transfer coefficient, B.t.u./[(hr.) (° F.) (sq.ft.)] at $\mu_s/\mu = 1.0$

HP = horsepower

HP_v = horsepower per unit volume

k = thermal conductivity

N = impeller speed

N_p = power number, $Pg/\rho N^3 D^5$

N_{Re} = Reynolds number, $ND^2 \rho/\mu$

P = power

R = tube wall resistance, (hr.) (° F.) (sq.ft.) / (B.t.u.) / (ft.)

S_c = coil spacing between tube centers

T = tank diameter

U = over-all heat-transfer coefficient, B.t.u./[(hr.) (° F.) (sq.ft.)]

Z = liquid depth

Z_o = height of coils

ρ = density of fluid

μ = viscosity at tank temperature

μ_s = viscosity at tube surface temperature

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mixing

CORRECTION

In a paper titled "Cocurrent Liquid-Gas in a Pipe-Line Contactor" by George E. Alves (C.E.P., September 1954, page 449) the following changes have been requested.

Page 454, Table 2

Under v_{Lc} change 0.17 to 0.12 in both entries.

Under $(N_{Re})_{Lc}$ change 1505 to 1038 in both entries.

Page 454, Figure 10

Under $(N_{Re})_L$ in the legend, the first entry should be 0 (zero) not the small circle.

Page 455, Figures 11a and 11b and page 456, Figure 12

For the footnote (see*), the \times (cross) should be X (letter, as shown in notation).

Page 456, Notation

Δp should be Δp .



some considerations of

cost

in the design of

pressure vessels

Val Weiler

A. O. Smith Corporation,
New York, New York

*Presented at one-day
meeting of New York
Local Section.*

Recent market developments have emphasized the importance of cost estimation and the need for its wider understanding. This article is meant to be a guide to the problems encountered in cost estimation for pressure vessels, but not an estimating manual.

Material Costs

The final cost of pressure vessels is usually related to the basic material cost, but this is not always true for many of the high-temperature processes now in use. Table 1 is a list of 12 common steels that can be purchased readily to consistent mill analyses, and about which the physical properties are clearly established.

Table 1 shows an index of the relative costs of the various steels for a plate $\frac{3}{4}$ in. \times 120 in. \times 228 in., such as would be used to make a typical 10-ft. section of a 6-ft. diameter vessel. This size of plate is selected since it represents a norm in steel pricing without unusual penalties for gauge, length or width. A most important factor in selec-

tion of material is the unit of cost per unit strength, also shown in this table. Both indices have been corrected to show the most commonly used material, carbon steel A.S.T.M. A285 Grade C FBQ, as 1.00. Table 1 shows that, although the material cost of 18-8 type 316 steel is 14.2 times the cost of ordinary carbon steel as purchased, it is only 10.4 times the cost per unit of strength at 650° F. and 5.8 times the cost per unit of strength at 900° F. Of particular significance in this table is the comparison of ordinary carbon steel with the 1% chrome ½% molybdenum (A301), and the 4% to 6% chrome ½% molybdenum. At 900° F. the cost of A301 is about 94% that of carbon steel per unit of strength, and 4% to 6% chrome steel is about 305%. This will be discussed in more detail later in this paper.

It should be pointed out that the above comparisons do not necessarily mean that all of these materials would be suitable for fabrication of pressure vessels that are designed for 900° F. Many other properties at elevated temperatures must be considered, such as creep value, resistance to embrittlement of various types, and tendency toward graphitization.

Fabrication Costs

As an additional comparison, Table 2 shows the effect on costs of fabrication of these various materials into a finished pressure container. These data are for a cylindrical vessel (shells and heads only), constructed of A.S.T.M. A285 Grade C material, designed for 225 lb./sq.in. at 650° F. to A.P.I. A.S.M.E. code, with a factor of safety of 4 and 80%. The vessel fabricated from A285-C would be a 6 ft. x 40 ft. x ¾ in. wall vessel. Suitable corrections in wall thickness have been made in calculating the indices for vessels made from

Table 2.—Comparison of Basic Pressure Container Costs for a 6-ft. diam. x 40-ft. Long Vessel Designed for 225 lb./sq. in.

Steel	Index of Cost at 650° F.	Index of Cost at 900° F.
1. A285-C	1.00	1.00
2. A201	1.00	1.08
3. A212	1.01	1.12
4. A204-A	1.20	1.37
5. A225-B	1.13	1.31
6. A301	1.29	.81
7. 4-6 Chrome, ½ Mo.	2.50	1.63
8. Carillloy	1.17	.82
9. 11-13% Cr	3.25	2.55
10. 18-8 (T304)	3.42	2.50
11. 18-8 Cb (T347)	3.75	2.75
12. 18-8 Mo (T316-ELC)	4.40	3.00

the other steels, and consideration has been given where increase in wall thickness would require or justify change in code factors of safety, or use of non-destructive tests or stress relieving.

Again it is useful to compare A.S.T.M. A285 steel with the two steels of lower chrome ranges previously mentioned. Since these tabulations include all material and labor, it is interesting to note that although at 650° F. a 1%-chrome-steel vessel indexes 1.29 times carbon steel, and a 4% to 6%-chrome-steel vessel indexes 2½ times carbon steel, at 900° F. the basic pressure container for a vessel of these steels shows the ratio of 1.00; 0.81; 1.63. As another example, 18-8 molybdenum steel, which shows an initial cost of 14.2 times carbon steel in Table 1, shows a fabricated index of 3 times carbon steel in Table 2, after suitable adjustments have been made for physical strength at elevated temperature per unit of cost.

Table 3.—Comparative Cost of Installing a 12-in. Standard Forged Nozzle in Basic Pressure Container

Steel	Index of Cost at 650° F.	Index of Cost at 900° F.
1. A105-CL II	1.00	1.00
2. A105-CL II	.98	1.02
3. A105-CL II	1.00	1.06
4. A182 F-1	2.21	2.23
5. Manganese-Vanadium Forging	2.21	2.23
6. A182 F-11 or 12	2.21	2.15
7. A182 F-5	2.31	2.20
8. Carillloy T-1 Forging	2.18	2.10
9. A182 F-6	3.25	3.20
10. A182 F-304	3.11	2.95
11. A182 F-347	3.42	3.25
12. A182 F-316	3.71	3.52

Detail Costs

Comparisons of basic plate and basic pressure containers are not sufficient for comparing these materials. The economics of design of basic pressure containers, particularly in the high temperature range, is complicated very much by the cost of the addition of detail. Table 3 shows the relative costs of installing a 12-in. 300-lb. forged fitting into a basic pressure container. The most significant factor is that the savings apparent in the basic pressure container for some of the materials is not so readily obtained in the detail. For instance, as shown in Table 2, the index for the basic pressure container dropped from 1.29 to .81 for A.S.T.M. A301 compared to carbon steel, but with the addition of detail such as the nozzle, the ratio is 2.21 at 650° F. and 2.15 at 900° F. It is therefore very obvious that details should be minimized. For example, instead of forged fittings, wherever possible consideration should be given to bringing out connections through manway covers as studded outlets, and economy can also be effected by fabricating connections from plate, sometimes at a cost of only one third to one half the cost of forged fittings.

It must be emphasized that these tables are not presented as estimating manuals, but as guide posts to designers, both process and mechanical, to make them increasingly aware of what they can expect in the use of special materials and unneeded detail. For example, the A. G. Smith Corp. estimators are currently using some 75-100 published material pricing manuals and more than 275 labor charts arrived at by 29 years of time study to achieve an accuracy of plus or minus 2%. Even so, changes in material costs, fabrication methods and welding procedures or additions of more

Table 1.—Comparison of Basic Plate Costs

Steel	Ultimate Tensile Strength at 650° F. (lb./sq.in.)	Material Cost Index	Index of Cost per Unit of Strength at 650° F.	Index of Cost per Unit of Strength at 900° F.
1. A285-C	55,000	1.0	1.00	1.00
2. A201	60,000	1.12	1.03	1.12
3. A212-B	70,000	1.12	.88	1.12
4. A204-A (½% Mo)	70,000	1.78	1.41	0.92
5. A225-B (1.45 Mn, .08-.14 Va)	75,000	1.77	1.34	1.78
6. A301 (1-1½% Cr, ½ Mo)	60,000	1.89	1.74	0.94
7. 4-6 Chrome, ½ Mo	60,000	5.37	5.40	3.05
8. Carillloy	105,000	2.65	1.39	0.86
9. 11-13% Cr	60,000	7.80	7.15	5.6
10. 18-8 (T304)	75,000	10.42	7.70	4.75
11. 18-8 Cb (T347)	75,000	11.65	8.55	5.40
12. 18-8 Mo (T316-ELC)	75,000	14.20	10.40	5.80

modern equipment can easily cause changes in cost of more than 10% in one year on certain classes of equipment.

The general engineering contractors, perhaps more than anyone else, have realized this. With the development of a highly competitive market practically all of them have shifted responsibility for establishment of major equipment costs in their estimates, including pressure vessels, from their estimating departments to normal purchasing channels. The author knows of no major refinery, chemical, or petrochemical project bid in the last six months in which the general contractor had not protected himself by formal competitive bids on major equipment items before submitting his own proposal. In fact this has complicated the estimating problem of the author's company since approximately 80% of the estimating capacity is being used by the demands of engineering contractors, with sometimes as many as fifteen, but usually an average of six, asking for confirmed pricing for the same project, all with designs varying enough to require multifold estimating effort. Since many of the fabricators offer various proprietary constructions for the solution of the same specific problem, they are willing to offer special designs gratis or at nominal charge. Very unusual requirements can be evaluated by cooperative design and development contracts or through information available from mechanical or metallurgical testing programs.

We have now set forth some general indices for materials and fabrication and would like to continue by commenting on specific groupings of vessels.

Applications

In the author's experience, the pressure vessels of most industrial interest can be grouped as follows:

Group A—Shop-fabricated carbon steel vessels up to 10 ft. in diam.; for temperatures up to 500° F. and pressures to 500 lb./sq. ft.

Group B—Alloy protected, solid chrome or chrome-nickel and low-alloy steel equipment for temperatures up to 1,000° F. and pressures to 1,000 lb./sq. ft.

Group C—General synthesis reactor vessels for pressures from 1,000 to 45,000 lb./sq. in. and temperatures not exceeding 800° F.

Group A

This group represents by far the bulk of pressure vessels being purchased and consequently the group which most shops can produce. It is corollary to this that the highly competitive nature of this business at the volume being offered by present business levels has

resulted in an extremely erratic pricing structure, often of such a range as to appear to have no relationship to the cost of manufacture. It is unusual to have competitive bids—all from first class shops—in a range of less than 20%, although all to the same exact specification for materials and fabrication. In one extreme case recently, a public government bid was opened for air storage tanks. Of the fourteen bidders, all were evenly spread between the low bid of \$323,000 and the high bid of \$534,000. There could be no confusion in the specifications to justify this variance. It is paradoxical that although this group is the easiest for which to establish estimating methods through pound price curves, etc., the competitive and erratic nature of the bidding is far beyond the probability of error of any method of estimating. It is suggested, in these cases, that accurate weight determinations be made of the vessels. If this weight breakdown is made with sub-totals for shell, heads, connections, supports, lining, internals and other detail, the fabricator can quickly determine a fairly accurate cost. The author suggests that this weight breakdown plus a sketch or drawing of the vessel be sent to at least three fabricators with a request for estimating prices.

Group B

The past five years has seen a much better functional understanding by designers in the study of solid alloy vs. alloy-protected equipment. General corrosion studies and realization of some of the specific mechanical-metallurgical operating problems, such as susceptibility to stress, corrosion cracking and graphitization, have disproved many of the original claims of panacea made for the higher alloys. Conversely it has led to much constructive research in such materials as the lower-range-chrome steels, now being increasingly used at substantial savings in such operations as catalytic reforming. The same has been true in the lower range nickel steels in such applications as ethylene plants, or other applications requiring high impact values at low temperatures. Correlation of operating experience, careful liner limitation tests, improved metallurgical control of materials, and improved welding procedures have allowed integrally bonded and applied liners to take their place in the economic pattern of this group.

A convenient yardstick for comparison of costs of applied versus integrally bonded liners would place the equalizing point for diameters up to 6 feet, regardless of length-to-diameter ratio, at about 1½ in. wall thickness. As the

diameter increases to 12 feet a more careful balancing of pressure and L/D ratio must be made. Most of the larger-diameter equipment is usually either lower-pressure fractionating columns or coking chambers and both methods of lining should be considered down to a thickness of ½ in. Notable exceptions would be special applications such as catalytic polymerization reactors and desulfurization vessels, with diameters up to 10 feet, and for use at temperatures up to 900° F. and pressure to 1,000 lb./sq. in. These processes definitely indicate applied liners or special constructions. These could be solid alloy or composite plate inner shells approximately ½ in. thick encased in a pressure-bearing cylinder constructed from approximately ¼-in. layers of inexpensive carbon or low-alloy steels in the medium or high tensile range. Such applications properly engineered can sometimes be completely fabricated at not much over the basic mill cost of integrally bonded plate. The same type of construction can also be utilized where corrosion problems dictate nonferrous or noble metals as protection.

Assignment of suitable allowable stress values up to 1,000° F. has led to increased use of the ½% to 1½% chrome ½% molybdenum steels in many applications instead of the higher chrome steels. Proper control by the steel mills of the impurities in lower-chrome steels has enabled the fabricators to eliminate cracking problems heretofore so prevalent in the medium-range-chrome steels. Many of the special welding preheat, post-heat, and special heat treatment and quenching requirements that have contributed so much to the cost of higher-chrome steels are no longer necessary. The lower-chrome steels are being utilized for bare metal reactor temperatures up to 1,000° F. competitively with other materials having metal temperatures of 400-500° F. in the same service achieved by refractory linings. Low-chrome steel vessels can be field erected and cat cracker reactors up to 37 feet in diameter have been field assembled. Composite plate, both integrally bonded and of the applied liner type, is available at reasonable costs in both the 18-8 and higher chrome steels. For instance, some of the desulfurization reactors used at present have 11%-13% chrome liners on 1½% chrome, ¼% molybdenum pressure-bearing shells.

Group C

Group C can be subdivided further into four subgroups. (1) The 1,000 to 4,000 lb./sq. in. range for processes such as urea manufacture, hydrogenation, synthesis of ethanol from ethylene, etc.

With few exceptions all of these processes require vessels with large L/D ratios in diameters from 20 in.-48 in. They also require a wide variety of special materials for corrosion protection, the more common of which are lead, copper, Monel, Inconel, silver and a variety of the 18-8 or chrome steels. In these services the basic pressure container costs are reasonably uniform and final cost is influenced principally by selection of corrosion-resistant material and the manufacturing procedure necessary to secure it adequately in place. Closures of conventional ring or confined gasket type are quite generally used up to 30-in. diameter and 2,500 lb./sq.in. Delta joints are used in the whole diameter range, generally from 2,500 lb./sq.in. to 4,000 lb./sq.in. Basic pressure containers rarely require steels of over 85,000 ultimate tensile strength and are designed with normal code factors of safety. Corrosion protection is supplied by a variety of methods. It may be part of an integrally bonded or applied liner pressure container; expanded, deposited or made as inner shells upon which are wrapped the pressure container. The same basic cost considerations however are still a good starting point, except that percentage change in price is less marked, since it is almost a necessity that the alloy or other metal protection be limited to a practicable thickness.

(2) Synthesis equipment, generally for ammonia or methanol, in the range of 4,000 to 5,500 lb./sq.in. This is usually carbon steel equipment. By far the greatest number of high pressure vessels constructed have been in this range within 30- to 42-in. diam. Common steels of not over 80,000 lb./sq.in. ultimate tensile strength have proven economical when designed with a factor of safety of 4 on the ultimate strength. Economy of design is principally effected by the end closures used and the ability to keep all openings in top and bottom heads rather than through shells. The majority of installations have Bridgman-type closures, although the use of Delta-type closures can save as much as from \$5,000 to \$15,000 per vessel. Prices are generally within the range of 45 to 60 cents per pound, not including internal catalyst baskets or exchangers.

(3) The third grouping in this section would cover pressures from 7,000 to 15,000 lb./sq.in. in diameters of 16-36 in. The past year has seen plant expansion in this country alone of about 400 tons per day of ammonia capacity operating in this pressure range. All of the high-pressure vessel equipment has been or will be contracted for with factors of safety between 3 and 4 on ultimate strength but not less than 2 on yield point from steels in the range of

90,000 to 105,000 ultimate tensile strength. The Delta closure has been used almost exclusively. The economics of design are not only dictated by these factors, but in addition force reconsideration of the basic design formulae themselves. For instance, the three or four generally accepted design formulae might show a divergence of 5%-8% in calculated wall thicknesses at 5,000 lb./sq.in., while at 13,000 lb./sq.in. the divergence could be closer to 60%. As an example, on a 24-in. diameter vessel this could mean a wall thickness of from between $8\frac{1}{2}$ to 14 in. Although cylindrical shell sections can be fabricated in this range, the effect on flange design is more pronounced and demands that theoretical formulae be proven by actual testing. Fortunately this has been accomplished and sufficient assurance is available to give the necessary state regulatory bodies and insurance companies confidence in the designs being operated. Reactors in this class of close to 400,000 lb. have been fabricated. Designs and necessary shipping clearances have been obtained to permit up to approximately a one million pound vessel if needed. This may be realized if certain processes, particularly coal hydrogenation, become commercially important.

(4) The last and most nebulous group in this class are the vessels in the 15,000 lb./sq.in. to 45,000 lb./sq.in. range. The general knowledge of this equipment is limited, principally because of commercial secrecy agreements between process licensors and users. Assuming that the materials available commercially at present have yield strengths in the 80,000 lb./sq.in. range and ultimate strengths of not much over 100,000 lb./sq.in., and that factors of safety not much below 2 on the yield are indicated, to be practicable at all, designs must introduce a precompressibility consideration.

The fact that high-pressure storage vessels are available should not be overlooked in consideration of gas storage problems.

Conversations with many people preparing estimates for the labor costs involved in field assembly and welding of large-diameter class I pressure vessels indicate a considerable variation in cost, roughly from \$200 to \$450 per ton. There is also considerable concern that many hidden costs are never revealed, such as those included in supplying the erector with services or utilities.

This has led to increased interest in the possibilities of shipping completely shop fabricated vessels in very large diameter, or shipment in large assemblies with a minimum of field welding. The economics of this procedure are dictated

principally by several factors:

1. The labor conditions at the job site.
2. Whether the shipment can be made employing common carriers with controlled rates, instead of contract carriers, whose rates are not controlled.
3. Whether the additional cost of heavier lifting equipment can be justified.

In the first consideration, evaluation should be made as to whether constant supervisory costs can be reduced by cutting total time in the field. As an example of the second factor, barging costs for a lot of four large vessels from Houston, Texas, to the East St. Louis area by common carrier was quoted at under \$4,000. The minimum bid for the same shipment by contract carrier for half the distance from Milwaukee to East St. Louis was \$34,500. Recently shipments have been made of vessels as large as twenty-six feet in diameter. In addition, consideration has been given to shop installation of internal detail and even refractory linings from the standpoint of both cost and quality control. At the time of this writing, the author's company, working with the manufac-

costs

turer, has successfully shop-installed and shipped refractory linings in sixteen catalytic reforming reactors.

A current paper entitled "The Influence of High Strength Materials on the Design and Fabrication of Lateral Vessels," which was delivered by G. E. Fratcher, chief engineer of our process equipment division at the Petroleum Division Conference of the A.S.M.E. at Los Angeles in September, 1954, gives some further data on the subject of high pressure vessels.

CORRECTION

In "A Laboratory for Pilot-Scale Distillation" by J. E. Friden and T. G. Stack (March, 1954, page 151), a line was dropped in the first column under the heading **Building and Utilities**. The first sentence in that paragraph should read as follows:

"The distillation building measures 77 by 73 ft. and is of brick and steel construction."

testing of reproduced vapor-phase catalysts

M. G. Pelipetz, L. V. Frank, H. H. Ginsberg,
M. L. Wolfson, and E. L. Clark

Bureau of Mines, Bruceton, Pennsylvania

The development of a one-stage hydrogenation catalyst for the conversion of middle oil to high-grade gasoline was perfected in Germany during World War II. Quantities of this catalyst, known as K-536, were shipped to the United States at the end of the war and studied by the Bruceton Development Laboratories and by the Demonstration Plant of the Bureau of Mines at Louisiana, Mo. Hydrogenation tests were satisfactory. The Bruceton laboratories of the Bureau of Mines were instructed to reproduce this catalyst. Using Filtrol-SR catalyst, treated with hydrofluoric acid as a support, a Bureau of Mines variation of K-536 catalyst was prepared. This prepared catalyst showed satisfactory activity and physical stability in a continuous operation of five weeks. The gasoline was of cycloaromatic nature with a motor octane number of 77 to 80, depending on the stock used.

Destructive hydrogenation of coal for the production of gasoline was carried out in Germany in two steps:

1. Hydrogenation of powdered coal, suspended in a heavy oil, with finely dispersed catalyst to produce a middle oil with an end boiling point of 617° F.

2. Hydrogenation of middle oil over a fixed-bed catalyst to produce gasoline.

The conversion of middle oil to gasoline by hydrogenation was accomplished with a catalyst containing 10% tungsten sulfide on activated clay. However, the nitrogen- and oxygen-containing compounds in middle oils obtained from coal necessitated a presaturation step in

which the oil was hydrogenated with 100% tungsten sulfide or 25% tungsten sulfide plus 3% nickel sulfide on activated alumina (3).

Later at Welheim a one-step splitting catalyst was developed for hydrogenation of middle oils obtained from pitch hydrogenation. Its support consisted of 40 parts of activated clay (activated with hydrochloric acid) and 60 parts of unactivated clay, and this mixture was treated with approximately 70% hydrofluoric acid, impregnated with zinc oxide and chromium oxide, and neutralized with ammonium hydroxide until neutral or slightly alkaline. A solution of ammonium molybdate $(\text{NH}_4)_2\text{MoS}_4$ was then added, followed by the addition of flowers of sulfur (1). Hydrogenation tests with it by the Bureau of Mines in a bench-scale continuous unit at Bruceton, Pa., and on a large scale at Louisiana, Mo., produced satisfactory results. It was therefore decided

to reproduce this catalyst with materials of domestic origin.

Preparation of Catalyst

Analytical data obtained at Bruceton (Table 1) were in good agreement with the German information. Of the available domestic materials, one produced by the Filtrol Corp., and synthetic silica-alumina manufactured by the Davison Chemical Corp. were chosen for preparation of catalyst K-536. The Davison Chemical Corp. was willing to reproduce the K-536 catalyst with synthetic silica-alumina as a support. Bureau of Mines preparations were therefore made with Filtrol SR. The Filtrol Corp. offered valuable information concerning the handling of this clay.

Molybdenum was to be added as ammonium molybdate. This salt is difficult to prepare and not commercially available. Four lots of it were prepared at Bruceton, but their contents of sulfur and molybdenum were not uniform. The lot closest to the theoretical composition was used in the preparation of catalyst A. To circumvent the cumbersome synthesis, a solution of commercial molybdenum trioxide in ammonium sulfide was used in preparation of B and C batches of catalyst. This method proved to be entirely satisfactory as shown in tests of catalyst B. List of tested catalysts is presented in Table 2.

Table 1.—Analysis of German Catalyst K-536

Constituent	Wt. %
Mo	0.48
Cr	1.27
Zn	2.94
S	2.39
F	3.26
NH ₃	1.12
SiO ₂	54.66
Al ₂ O ₃	16.21
MgO	1.70
CaO	0.72
Fe	2.10

Table 2.—List of Catalysts Tested

Designation of catalyst*	Origin	Support	Mo	Cr
K-536	Ruhr-Öel, Germany	Presumably bentonite clay, activated with oil	1.4% as $(\text{NH}_4)_2\text{MoS}_4$	2.5% as CrO_3
A	Bureau of Mines	Filtrol SR	1.4% as $(\text{NH}_4)_2\text{MoS}_4$	2.5% as CrO_3
B	Bureau of Mines	Filtrol SR	0.75% as MoO_3 dissolved in $(\text{NH}_4)_2\text{S}$	2.5% as CrO_3
C	Bureau of Mines	Filtrol SR	0.75% as MoO_3 dissolved in $(\text{NH}_4)_2\text{S}$	2.5% as CrO_3
Davison	Davison Chemical Co.	Synthetic silica-alumina	1.4% as $(\text{NH}_4)_2\text{MoS}_4$	2.5% as CrO_3

* In all cases, Zn analyzed 3.5% as ZnO, S 7% as flowers.

Activity Tests

EQUIPMENT

Activity tests were performed in the bench-scale, continuous unit (4) shown in Figure 1. An oil-hydrogen stream was passed through a preheater, maintained at 842° F., into the bottom of the reactor. In the middle portion of the reactor, which was $\frac{3}{8}$ in. in diam., 100 ml. of catalyst was confined. The top and bottom parts of the reactor were filled with stainless steel spacers. Reported temperatures represent averages of the temperatures measured at three points in the catalyst bed. The products and excess hydrogen were emitted through the top of the reactor into a separator where the liquid and gaseous streams were divided.

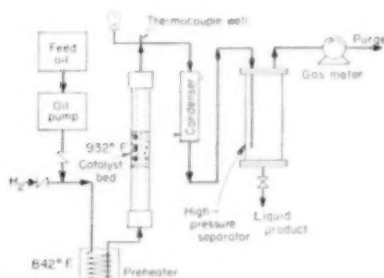


Fig. 1. Flow diagram for vapor-phase hydrogenation unit.

A durability test was made with the reactor arrangement shown in Figure 2. In this arrangement 150 ml. of catalyst was charged and higher rates of oil and hydrogen were used than in the other unit.

The catalyst was located in the upper part of the reactor so that the products left the reactor without passing through a heated zone. Feed oil and hydrogen were introduced at the bottom of the reactor and preheated while passing through a part of the reactor filled with spacers. The feed line for hydrogen was heated to 850° F.

Tests with Welheim Catalyst

The reactor used to test the catalysts was of $\frac{1}{4}$ -in. I.D. The catalysts were $\frac{1}{8} \times \frac{1}{8}$ in. in size. Various methods of preparing suitable catalyst particles from the 10-mm. pellets available were investigated in the first series of tests. For operation 1, 6-8 mesh irregular catalyst gran-

Table 3.—Characteristics of Middle Oil Used for Catalyst Activity Tests

Cut	Vol. %
0° to 400° F.	35.6
400° F. to 617° F.	64.4
Element	Wt. %
H	10.07
C	85.86
N	0.80
S	.22
O	3.05

Table 4.—Conditions of and Products from Hydrogenation of Middle Oil with 100 ml. Welheim Catalyst K-536 at 9,000 lb./sq. in. gauge

Type of Catalyst	Granules	Pelleted		Extruded		
Operation No.	1	2	3	4	5	6
Weight of catalyst charge, g.	61.3	111.1	111.1	71.3	71.3	71.3
Temperature, ° F.	930	932	932	932	935	932
Feed rate, g./hr.	100	100	180	115	100	180
Product, weight % of feed						
liquid	82.7	78.2	86.2	74.9	72.9	81.9
C ₃ and heavier in gaseous state	5.6	7.5	4.8	9.1	8.5	4.3
	88.3	85.7	91.0	84.0	81.4	86.2
C ₁ to C ₂ inclusive	11.0	14.0	8.3	15.6	18.4	12.7
Hydrogen used, weight % of feed	3.0	3.8	2.5	4.0	4.1	3.1
Product oil, ultimate composition						
hydrogen	11.53	12.05	11.45	11.94	11.74	11.45
carbon	87.34	87.16	87.10	87.84	87.69	87.63
nitrogen	0.24	0.16	0.21	0.09	0.04	0.13
sulfur	0.04	0.03	0.08	0.05	0.06	0.08
H/C atomic ratio	1.58	1.66	1.63	1.63	1.61	1.59
Gasoline (400° F. E.P.) in liquid product, wt. % of product (includes distillation loss)	71.7	82.45	68.2	84.6	83.6	74.7
Gasoline (400° F. E.P.) in liquid products, wt. % of feed	59.3	64.5	58.8	63.5	61.1	61.2
Octane No. of gasoline, motor	79.1	77.6	77.0	77.2	78.0	78.5
Ultimate composition of gasoline						
hydrogen	12.24	12.55	11.75	12.32	12.03	11.97
carbon	87.18	86.78	86.88	87.51	87.08	87.70
nitrogen	0.13	0.08	0.15	0.03	0.03	0.12
sulfur	.04	.02	.03	.02	.05	.04

catalysis

Table 5.—Conditions of and Products from Hydrogenation of Middle Oil with 100 ml. Reproduced Catalysts at 9,000 lb./sq. in. gauge

Catalyst identification	A		B		Davison
Type of catalyst	Pelleted	Extruded	Pelleted	Extruded	Pelleted
Operation No.	7	8	9	10	11
Weight of catalyst charge, g.	93.1	60.9	104.5	69.9	70.0
Temperature, ° F.	929	931.6	932	930	930.8
Feed rate, g./hr.	101.1	88.5	96.4	98.5	103.8
Product, weight % of feed					
liquid	84.5	82.4	85.2	77.7	84.2
C ₃ and heavier in gaseous phase	5.3	6.4	5.0	8.6	3.9
	89.8	88.8	90.2	86.3	88.1
C ₂ to C ₃ inclusive	9.6	10.12	8.88	12.9	10.2
Hydrogen used, weight % of feed	2.8	3.00	3.1	4.0	2.8
Product oil, ultimate composition					
hydrogen	11.58	11.47	11.97	12.24	11.68
carbon	87.28	87.92	87.40	87.27	87.63
nitrogen	0.25	0.24	0.14	0.12	0.13
sulfur	.05	.07	.06	.04	.08
H/C atomic ratio	1.59	1.57	1.64	1.68	1.57
Gasoline (400° F. E.P.) in liquid product, wt. % of product (includes distillation loss)	72.3	76.4	84.5	76.7	72.0
Gasoline (400° F. E.P.) in liquid products, wt. % of feed	61.1	63.0	65.7	65.3	60.6
Octane No. of gasoline, motor	79.2	79.3	77.4	77.7	78.5
Ultimate composition of gasoline					
hydrogen	12.52	12.16	12.52	12.28	11.97
carbon	87.04	87.38	87.38	87.44	87.70
nitrogen	0.26	0.10	0.09	0.09	0.12
sulfur	.07	.04	.02	.05	.04

ules were prepared by crushing the catalyst. The $\frac{1}{8} \times \frac{1}{8}$ -in. molded pellets, prepared by adding 1.5% graphite to pulverized catalyst and shaping the pellets on a Stokes molding press, were tested in operations 2 and 3. Extruded $\frac{1}{8} \times \frac{1}{8}$ -in. pellets were prepared for operations 4 to 6 by mixing catalyst powder with distilled water and re-extruding the plastic mass in a hand extrusion press. The catalyst shape greatly affected its density. Compared with 71.5 g. for re-extruded catalyst and 61.3 g. for granules, 100 ml. of pellets weighed 111.1 g.

The feed stock was a middle oil, boiling below 617° F., produced in operation 6 at the Demonstration Plant by hydrogenation of Kentucky coal, at 865° F. and 8,000 lb./sq.in. The characteristics of the oil are presented in Table 3. The feed stock contained 35% of material boiling below 400° F., which is somewhat more than normally observed in a middle oil obtained from coal. For example, Hirst *et al.* (2) anticipated the production of a middle oil containing less than 20% of material boiling below 400° F. To obtain suitable activity tests, operating conditions were such that at least 40% of the high-boiling fraction of the feed oil was converted to gasoline. All tests were performed at 9,000 lb./sq.in. gauge plant pressure, corresponding to a partial pressure of hydrogen of 8,600 lb./sq.in. gauge. In the operational procedures used, German practice was followed. The catalyst was activated at 932° F. for 16 hr. The rate of hydrogen to feed was 10.5 std.cu.ft./

(hr.) (100 g. of oil) (hr.). The granules were investigated only at the standard German rate of 100 g. of oil/(100 ml. of catalyst) (hr.), but the pelleted and extruded catalysts were tested also at different feed-to-catalyst ratios.

Data of Table 4 indicate that the three types of catalyst yielded virtually identical products. At a given feed rate the re-extruded catalyst appeared to effect the most extensive splitting of the feed oil. However, since the product recovery was not quantitative and since this catalyst was run at a slightly higher temperature in operation 29 than the other catalysts tested at the same feed rate, the differences in the product distributions cannot be due to differences in catalyst types. This conclusion is supported by the fact that both pelleted and re-extruded catalysts gave identical results at a feed rate of 180 g./hr.

Tests with Reproduced Catalysts

Pelleted and extruded catalysts B-12 and B-13, prepared by the Bureau of Mines, were tested in operations 7 to 10. A pelleted catalyst prepared by the Davison Chemical Corp. was tested in operation 6. Data obtained in these tests are presented in Table 5. Comparison of the results in Tables 4 and 5 indicates that the reproduced catalysts were as active as the Welheim in splitting and refining middle oil. There was little difference, if any, between the extruded and pelleted reproduced catalysts. This fact is in accord with the data obtained with the Welheim catalyst.

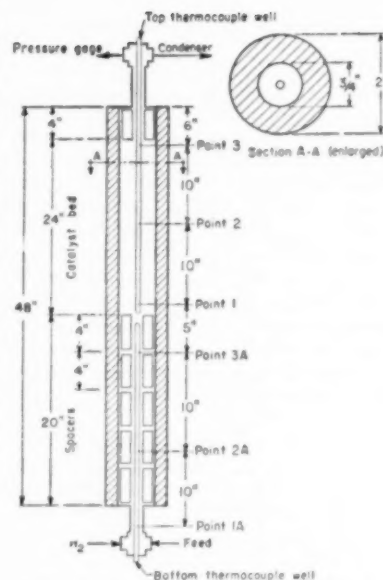


Fig. 2. Reactor for vapor-phase hydrogenation unit.

A mechanically strong pelleted catalyst was chosen for a durability test. This catalyst was prepared similarly to that used in operation 9 and tested with the same feed stock but in the reactor shown in Figure 2. After conclusion of the 4-week test as planned, a product consisting of middle oil plus naphtha (from Demonstration Plant operation 9) was hydrogenated during the fifth week. The unit was operated continuously and without any difficulty for more than 800 hr. Table 6 shows the results of the 4-week durability test. The close similarities among ultimate compositions, specific gravities, and octane numbers of the gasolines as well as among compositions and yields of the product oils indicate that the catalyst did not lose any activity during the test. Examination of the catalyst itself showed no loss in weight, damage, or carbon deposit. The crushing strength of the catalyst had almost tripled after 5 weeks of operation. Its constant high activity and excellent mechanical strength indicate that this catalyst is satisfactory for use in large-scale equipment for the hydrogenation of middle oil derived from coal.

Table 6.—Conditions of and Products from Hydrogenation of Middle Oil with 150 ml. Pelleted Catalyst C at 9,000 lb./sq. in. gauge

Weeks of Operation	1st	2nd	3rd	4th
Weight of catalyst charge, g.	157.2	157.2	157.2	157.2
Temperature, ° F.	933	932	933	934
Feed rate, g./hr.	150	150	150	150
Product, weight % of feed				
liquid	80.3	79.6	79.7	80.5
C ₄ and heavier in gaseous phase	8.75	6.2	7.6	7.1
	89.05	85.8	87.3	87.6
C ₁₂ , C ₁₀ , and C ₈	11.91	13.11	12.92	12.70
Hydrogen used, weight % of feed	3.85	3.94	3.85	3.80
Product oil, ultimate composition				
hydrogen	12.28	12.20	12.18	12.18
carbon	87.59	86.92	87.64	87.34
nitrogen	0.07	0.06	0.06	0.07
sulfur	.02	.05	.04	.02
H/C atomic ratio	1.68	1.68	1.67	1.67
Gasoline (400° F. E.P.) in liquid product, wt. % of product (including distillation loss)	86.4	90.0	88.2	85.8
Gasoline (400° F. E.P.) in liquid product, wt. % of feed	69.4	71.7	70.3	69.1
Octane No. of gasoline, motor	76.9	77.0	76.8	77.2
Ultimate composition of gasoline				
hydrogen	12.68	12.74	12.60	12.38
carbon	87.42	87.51	86.95	86.99
nitrogen	0.03	0.07	0.06	0.04
sulfur	.02	.04	.04	.07

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3. Ministry of Fuel and Power, "Report on the Petroleum and Synthetic Oil Industry of Germany," London (1947).
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the

turbine

as a mixing tool

E. J. Lyons and N. H. Parker

Turbo-Mixer Division,
General American Transportation Corporation,
New York, New York

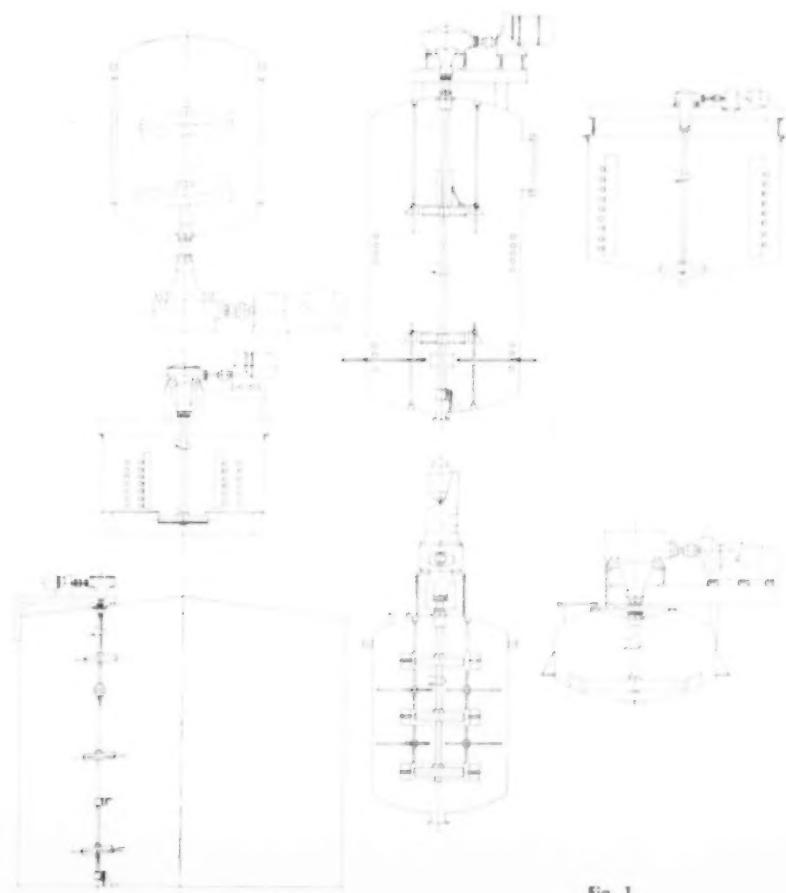


Fig. 1.

Most versatile of mixing elements, the turbine in its many forms has a range of application from simple, slow-motion blending to an intensive multi-phase dispersion, from mixtures of alcohol and water to a million-centipoise acetate dope. It is also adaptable to tank shapes from the shallow pan to the tall and narrow "stovepipe."

Although mixing can be adapted to most tank conformations, experience dictates that in each service there is a preferred shape for optimum efficiency. Figure 1 illustrates this relationship showing the shallower tank for viscous liquids or dense slurries and the taller tank for continuous staged systems or maximum retention and use of the gas phase in an absorption.

For maximum efficiency, too, a variety of turbine shapes is required to cover all applications. The back-sloped blade offers maximum power economy, particularly with high-viscosity mixtures. The straight blade develops a higher discharge velocity for dispersion-type service requiring localized intense shear. The same environment is provided by the impeller and stator-blade assembly, which permits the most positive impeller discharge control, critical in some solid suspensions.

Chart Provides Design Criteria

It is of course possible to adjust a mixer element, whether paddle, propeller, or one form of turbine, to satisfy any service; however higher horsepower, slower heat transfer, longer retention, or stratification will result. The selection chart (Figure 2) gives an example of these variations in the criteria and gives tank and impeller relationships for the basic services. The chart is included purely as a guide for the design engineer in preliminary sizing of tank and mixer for each of the basic services. Balancing the properties of the materials and the severity of the service, he can utilize the general limits of the chart to arrive at a first approximation of the equipment dimensions.

An example of the use of the chart occurs in the leaching of a 50% water slurry of a 20-mesh, 3.8-gravity ore by a dilute acid of equal volume, the heat of solution to be removed by cooling coils. The controlling factor is suspension of the solids to promote the reaction in

which heat is developed. The criteria for solid suspension are circulation and liquid velocity sufficient to overcome the settling rate of the solids. The same criteria are also pertinent to good heat transfer and reaction. The large particle size and gravity difference between solids and solution suggest fast settlement. Best impeller position is therefore on the vessel bottom so that its radial discharge will sweep all solids up into the tank. In order to maintain maximum distribution of solids yet allow sufficient depth of liquid for the cooling coils, the maximum tank-height ratio of 1:1 from the chart would be used. Impeller ratio is regulated by reaction and suspension, with the latter controlling because of particle size. Tank depth and particle size in this case suggest a large impeller diameter, or a ratio of about 2.5:1. As the circulation pattern now established is radially across the bottom and up the sides, the slurry will flow up across and through a helical coil for good transfer rate. This pattern will be assured by four full vertical baffles mounted inside the cooling coil (see Figure 1). With this size information and reference to the horsepower

chart in Perry's handbook (3), the preliminary design is complete.

This information should be sufficient for those estimates which are too preliminary or confidential to review with the mixer engineer, who should be consulted at the earliest possible stage in the development of the process in order that advantage may be taken of his specialized knowledge and experience. His guidance is essential in the finalization of the most efficient design. The manufacturer will bear the ultimate responsibility for its successful operation.

The criteria, which vary with each service, define what mixer functions contribute most to optimum efficiency. By the same reasoning, they are also the controlling functions in extrapolation of laboratory or pilot data to plant scale in each service. No generalized scale-up formula will give the proper weight to data on both blending and extraction.

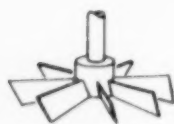


Fig. 2. Pitched Turbine. New England Tank & Tower—prior 1910.

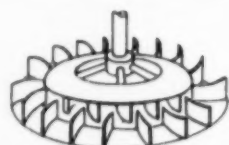


Fig. 3. Shrouded Turbine. Johnson-Turbo-Mixer—1913.

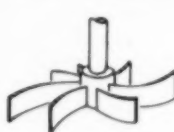


Fig. 4. Open Tilted Turbine. Turbo-Mixer—1932.

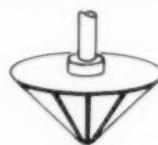


Fig. 5. Cone Lifter. Turbo-Mixer—1932.



Fig. 6. Center Disc Turbine. Turbo-Mixer—1934.



Fig. 7. Gas Type Turbine. Turbo-Mixer—1935.



Fig. 8. Three Blade Turbine. Pfaudler—1935.

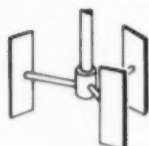


Fig. 9. "Brumagin" Turbine. Struthers-Wells—1937.

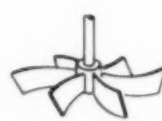


Fig. 10. Variangle Turbine. Patterson Foundry—1938.

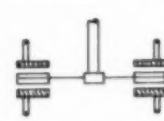


Fig. 11. Vaned Disc Gas Turbine. Int. Engineering—1939.

Figs. 2-11—Commercial Impeller Designs, Manufacturers, and Dates of Introduction.



Fig. 12. Straight Bladed Turbine—1556.

Turbine Mixing A.D. 1556

The turbine probably is the oldest mixing element applied on a mechanically driven unit. The earliest reference, in a wood cut of a turbine handling a gold-ore slurry in water, appears in Agricola's "De Re Metallica" (1) printed in 1556.

The designs commonly mentioned in the early literature of the tanning, dyeing, and alkali industries are paddle- and gate-type mixers. They were the most frequently used up to quite recent times. The advent of the chemical industry in the late 1800's renewed interest in the turbine, particularly for dry colors, vat dyes, and alkalies.

General use of the turbine in this

country started before the turn of the century, at the same time that a few applications for the propeller, both side and top entering, were initiated. Straight- and pitched-blade turbines were made by several manufacturers before 1910 (2). The curved-blade shrouded turbine with stator ring was first built by John Johnson in 1913 and subsequently became known as the Turbo-Mixer. Use of the turbine in its various forms expanded rapidly thereafter, replacing paddle-, gate-, and anchor-type mixers in those applications requiring controlled agitation.

Some of the many forms of turbine impeller are shown in Figures 2 through 11, each representing a type commonly used today.










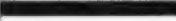

















SELECTION CHART				SHAPE RELATIONSHIPS FOR TURBINE DESIGNS		
SERVICE	MIXING DEVICE	RANGE	CRITERIA	TANK DIAMETER TO IMPELLER DIA. RATIO	TANK HEIGHT TO DIAMETER RATIO	IMPELLERS AND POSITION
BLENDING	TURBINE		1. VOLUME CIRCULATION	3:1 TO 6:1	UNLIMITED	SINGLE OR MULTIPLE
	PROPELLER					
	PADDLE					
	TANK VOL.	→ 1,000,000 GALS				
DISPERSION (IMMISCIBLE SYSTEMS)	TURBINE		1. DROP SIZE CONTROL 2. RE-CIRCULATION	3.0:1 TO 3.5:1	1:1 TO 1:2 IN STAGED MIXERS	AT/OR BELOW CENTER LINE OF LIQUID CHARGE
	PROPELLER					
	PADDLE					
	FLOW	→ 1,000 GALS/MIN				
REACTIONS IN SOLUTION (MISCIBLE SYSTEMS)	TURBINE		1. INTENSITY 2. VOLUME CIRCULATION	2.5:1 TO 3.5:1	1:1 TO 3:1	SINGLE OR MULTIPLE
	PROPELLER					
	PADDLE					
	CHARGE VOL.	→ 20,000 GALS				
DISSOLUTION	TURBINE		1. SHEAR 2. VOLUME CIRCULATION	1.6:1 TO 3.2:1	1:2 TO 2:1	AT/OR BELOW CENTER LINE OF LIQUID CHARGE
	PROPELLER					
	PADDLE					
	CHARGE VOL.	→ 10,000 GALS				
SOLIDS SUSPENSION	TURBINE		1. CIRCULATION 2. VELOCITY	2.0:1 TO 3.5:1	1:1 TO 1:2	DEPENDING ON PARTICLE SIZE. 1. IMP DIAMETER OFF BOTTOM. 2. ON BOTTOM.
	PROPELLER					
	PADDLE					
	% SOLIDS	→ 100 %				
GAS APPLICATIONS	TURBINE		1. CONTROLLED SHEAR 2. CIRCULATION 3. HIGH VELOCITY	2.5:1 TO 4.0:1	4:1 TO 1:1	1. MULTIPLE - LOWEST ONE IMPELLER DIAMETER OFF BOTTOM. 2. SELF-INDUCE, JUST BELOW LIQUID LEVEL.
	PROPELLER					
	PADDLE					
	GAS VOL.	→ 5,000 CU. FT./MIN.				
HIGH VISCOSITY APPLICATIONS	TURBINE		1. VOLUME CIRCULATION 2. LOW VELOCITY	1.5:1 TO 2.5:1	1:2 TO 2:1	SINGLE OR MULTIPLE
	PROPELLER					
	PADDLE					
	VIS.	→ 1,000,000 CPS				
HEAT TRANSFER	TURBINE		1. VOLUME CIRCULATION 2. HIGH VELOCITY ACROSS TRANSFER SURFACE	RELATED TO OTHER SERVICES	DEPENDS ON OTHER SERVICES BEING PERFORMED	SINGLE OR MULTIPLE. IMPELLER OPPOSITE TRANSFER SURFACE WHEN USING COILS
	PROPELLER					
	PADDLE					
	CHARGE VOL.	→ 20,000 GAL				
CRYSTALLIZATION OR PRECIPITATION	TURBINE		1. CIRCULATION 2. LOW VELOCITY 3. SHEAR CONTROL	2.0:1 TO 3.2:1	2:1 TO 1:1	SINGLE. AT/OR BELOW CENTER LINE OF LIQUID CHARGE.
	PROPELLER					
	PADDLE					
	CHARGE VOL.	→ 20,000 GALS				

Fig. 13. Selection Chart.

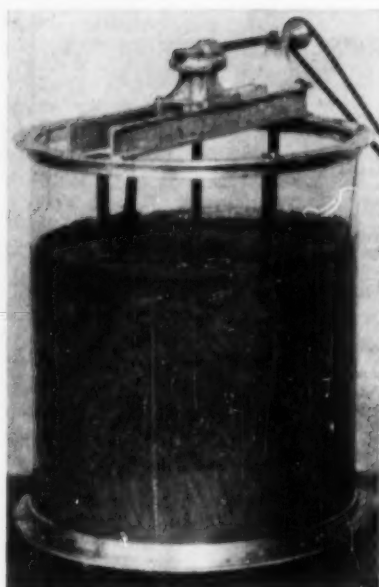


Fig. 14. Photograph of Laboratory Model of the Johnson Turbo-Mixer (Circa 1923).

Mixing Is Empirical

Mixing is not subject to a single codification. It is a unit operation which has developed from a practical application of the art to a fuller understanding of its theoretical aspects. The reverse has generally been true of the development of other unit operations. Mixing seldom exists by itself, but serves to promote other unit operations.

Knowledge of the characteristics, limitation, and power requirements of the turbine therefore came first from measurements on practical application of full-scale equipment in the field, theoretical calculations of horsepower, circulating capacity, viscosity effect, etc., being subsequently determined and verified against operating data. The front cover of this issue of C.E.P. contains an excellent illustration of basic studies being undertaken. In these a modern, laboratory technique demonstrates the well-known clover-leaf circulation pattern of a turbine impeller with the flow induced throughout the mass by the main discharge of the impeller. The pumping capacity of flat-bladed turbines, previously calculated from practice, can be checked with the length of light streaks in the photographs.

In practice, mass transfer rates have been calculated from operating data on specific systems. Investigative work of the type presented by Hixson, Drew, and Knox (7) gives significance to these calculations. Their dimension for a transfer unit facilitates a correlation of laboratory and production equipment for processes in which mass transfer is the controlling factor.

Process Determines Turbine

Some of the many forms of turbine impeller are shown in Figures 2 through 11. Each represents one variation of a type commonly used today, which was developed through experience for the service in which it performs; examples are a special gas impeller (Figure 7) and the vane disk (Figure 11) for dispersion of gas into a liquid. The lifter (Figure 5), operating in a continuous flow-mixing environment, produces a positive discharge head to raise the liquid level in its vessel or to pump the liquid through the balance of the system. The tilted impeller (Figure 4) and the Variangle (Figure 10) were developed to pump high-viscosity liquids more effectively. The Brumagin (Figure 9) produces an intensive shearing action. This diversification of design permits selection of the impeller that will achieve the desired result with maximum efficiency, maximum economy of time and power, and minimum operating cost.

The design of mixing devices is an excellent example of the application of chemical engineering to the simplification of equipment. The selection of the right impeller design for the service, rather than a random choice, is demonstrated in two typical process problems, acetate dissolving and countercurrent extraction.

Before the technique of dissolving acetates, having essentially true viscosity, was developed in connection with impeller mixers, acetates were dissolved in large and heavy sigma arm-type mixers. The first simplification was the use of paddle mixers, using the knowledge that with sufficient controlled circulation the

acetate particles will by attrition grind one another to complete solution. The greater pumping capacity and positive stream control of present turbine designs was the final improvement, leading to complete solution in the shortest cycle.

In the countercurrent extraction of immiscible liquids the progression in equipment has been from the large packed or gridded column to a series of much smaller staged mixers with separate settlers. The first refinement was a staged turbine mixer directly piped to a staged separating tower with the impeller providing the circulation (4). Then a vertical tower with single shaft and turbine-type impellers and a grid or mesh coalescing zone between stages for separation was developed (5). The simplest device to date consists of a column with rotary disks and interstage annular rings in which both the mixing of the two phases and their countercurrent separation are achieved within each compartment (6).

Future refinements in mechanical design will continue to extend the scope of the versatile turbine as a mixing tool.

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6. Reman, G. H., to Shell Development Co., U. S. Patent 2,601,674.
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Fig. 15. Open back sloped impeller (rubber covered) first built by Turbo Mixer and others about 1924.

Petrochemicals

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The Petro plant at Tuscola, Illinois was planned for the most efficient production possible. These factors were considered carefully:

RAW MATERIALS... natural gas is taken directly from the Panhandle Eastern pipe line compressor station at Tuscola for further processing.

FLOW OF MATERIALS... every production process is integrated. For example, while the main product of the ethylene unit feeds the ethyl chloride, ethyl alcohol and polyethylene plants, by-product hydrogen flows to ammonia manufacture, and also to the chloride process. The sulfuric acid plant not only supplies the

fertilizer market, but also the alcohol unit.

TRANSPORTATION... three railroads and two main highways converge at Tuscola for ease in transporting materials.

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industrial news

WISCONSIN NITROGEN PROCESS UNECONOMICAL

Although the Army Ordinance contract for development of the Wisconsin process for nitrogen fixation has been terminated, the Food Machinery and Chemicals Corp. announces that both laboratory and pilot plant operations will be continued. They will investigate difficulties encountered in the pilot plant. During the development of this process at the Sunflower Ordinance Works, Kansas City, a large amount of data in respect to this field of technology was developed but the economics for commercial production did not prove to be in line competitively with other processes now being operated on a large and integrated scale in the U. S.

The process makes use of a high temperature pebble heat exchange furnace to produce dilute nitric oxide. During the period of development substantial tonnages of high grade nitric acid were produced and the structures proved their ability to take continuous operation at 4,000 ° F.

PUMP TESTING

Insurance that each centrifugal pump shipped comes up to rated values, Dean Bros. has installed a modern, fully equipped pump test and research laboratory at its Indianapolis, Indiana, plant. Test conditions closely simulate the actual conditions under which the pump will operate on the job and allows recording the performance data on every pump for typical head capacity curve for future reference.



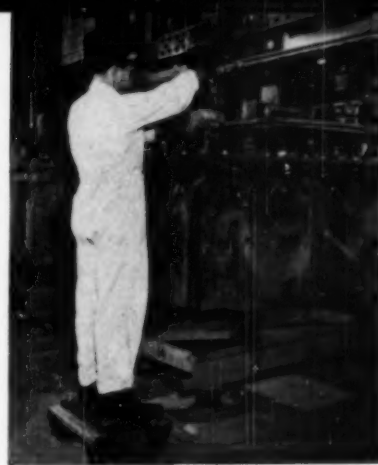
Testing facilities consist of a closed system in which water is circulated by the pump under study. Water flows from a large, pressure tight surge tank to the pump suction inlet at any of the four pumping stations. The use of the closed system affords accurate control of pump operation closely approximating actual service conditions. Vacuum suction conditions are simulated by exhausting the sealed surge tank with a vacuum pump. High pressure suction conditions are accomplished by loading the tank to the desired pressure with an air compressor. Duplication of NPSH condition can be demonstrated.

NEW FLUORINE CELL DEVELOPED

A medium-temperature electrolytic fluorine cell of advanced design developed by the engineers of Union Carbide seems certain to promise an increase in fluorine output. Developed in connection with the uranium 235 separation program, the new cell produces fluorine at lower cost, in less operating time, at a much higher rate and has doubled the life of previously available cells. Stimulated by the promise that the new cell holds in being adaptable to industrial processes, Carbide engineers have projected the idea into a typical plant to produce two tons of fluorine daily.

Cell construction was improved by use of a stress-relieved nickel base inner shell, additional center cooling tubes and a baffled water jacket. Cell operation has been improved by rigorous attention to anode to cathode spacing and alignment which has minimized anode polarization. The cell is normally op-

erated at 8 to 10 volts and 3,500 to 4,000 amps without interruption until breakdown. Current efficiency is about 90%. Routine maintenance consists principally of cell rebuilding and replacement, leak repair, and pump and valve repair and replacement. The cell is shut down about a half day per month.



MERGER OF FLUOR WITH SINGMASTER & BREYER

Fluor Corporation, Ltd., of Los Angeles and Singmaster & Breyer of New York have merged their experience, facilities and interests and yet are retaining their individual organizational identities. This affiliation has been brought about by a recent agreement whereby Fluor purchased control of 55% of Singmaster & Breyer stock. Both Fluor and S&B have been prominent in petrochemical plant engineering, with Fluor having integrated construction facilities. Both have also been active in ammonia and S&B has had a long background of experience in extractive metallurgy and heavy chemical minerals processing. Fluor maintains in Los Angeles a modern research and development laboratory, which will now serve the needs of S&B projects. Customers of either firm will be served in general by the facilities of both, according to the needs of the occasion. The combine will be served through Fluor's engineer-

ing staffs in Los Angeles, Houston, Toronto (Fluor Corp. of Canada), and Niagara Falls, Ont. (H. G. Acres), and Singmaster & Breyer in New York; also through Fluor's fifty sales engineers located in principal cities of the U. S. and foreign countries.

Fluor's financial resources are indicated by the 1953 financial report, which showed total assets of \$27 million, working capital of \$9 million, 1953 billing to clients of more than \$100 million, and with stock valued at \$11 million.

Frank Breyer, senior partner and co-founder of the New York firm, will become a Fluor director. Singmaster & Breyer directors will be divided evenly between Singmaster & Breyer and Fluor; all officers except the controller will be S&B former partners with Breyer as Chairman of the Board of S&B Inc. and W. H. Finkelday as President.

Fluor was founded in 1890, and S&B in 1927.

DOW EXPANDS MARKET RESEARCH

The formation of a research development section in the market research dept. of Dow Chemical Co., adds to its industrial planning program. The new groups responsibility will be to analyze specific industrial fields as a means of forecasting long-range trends and needs of various industries. The information will be used to aid Dow research and development groups in developing ideas for new company products. Dr. E. R. Boedeker, a member of the institute, will head the section handling the petroleum industry.

OLIN PLANS NEW PLANT

A new cellophane plant will be constructed in Olin, Indiana, a new town to be located along the Wabash River in Southeastern Ind., by the Olin Mathieson Chemical Corp. Engineered and constructed under contract with E. I. du Pont de Nemours, the plant will be in operation in the latter part of 1956 and will employ approximately 600 persons. This will supplement Olin's other cellophane plant at Pisgah Forest, N. C., which has been in operation for over three years.

CHEMICAL PROCESS NEWS

PUBLISHED BY CHEMICAL PROCESS DIVISION, THE M. W. KELLOGG COMPANY

DECEMBER 1954

NOTES ON AMMONIA

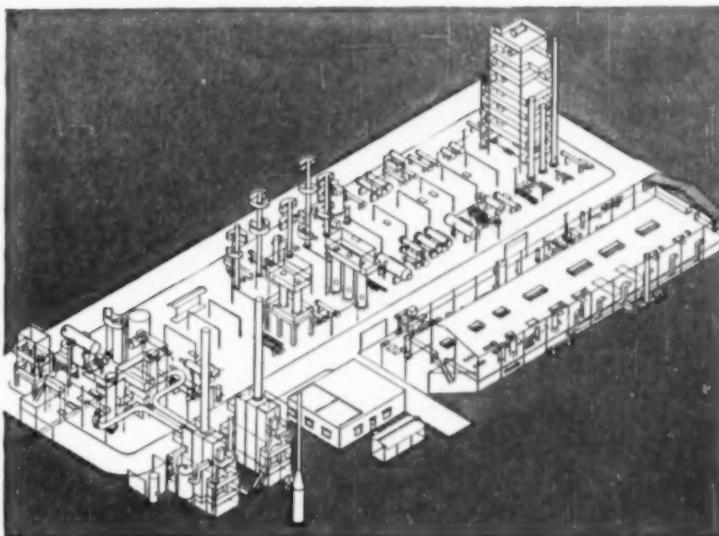
One of the latest developments in the ammonia field is Kellogg's radical reduction in investment expenditures required to build a plant. As evidence of this, the company was recently awarded a contract for a 300 tons-per-day plant in the Midwest at the unusually low investment cost of about \$50 per ton of annual capacity. Comparable plants have run upwards of twice this figure.

One source of this big saving lies in the fact that previous experience with Kellogg's high-pressure gas reforming step has resulted in refinements which increase its already high efficiency and more than proportionately decrease its cost. Furthermore, the process will employ only one synthesis section. In addition, operating experience with Kellogg ammonia converters has shown that they can be substantially reduced in size as can the heat exchangers without sacrifice of capacity.

These developments come on top of a considerable amount of ammonia manufacturing know-how which Kellogg has been acquiring since the early 1940's. For example, another of the company's contributions to ammonia synthesis is a reactor which closely approaches the ideal.

For a reaction rate high enough to produce profitable yields, a special temperature gradient must be maintained in the reactor. This requires extremely close control of temperatures throughout the catalyst beds—a job made more difficult by the fact that the exothermic reaction occurs at a temperature near that at which catalyst activity begins to deteriorate rapidly and construction materials are threatened by accelerated corrosive attack.

Kellogg solved this problem with a reactor which employs layers of catalyst with provision for injecting quench between the beds. The result is a converter that effectively controls removal of the heat from the reaction zone, giving virtually point-by-point temperature control throughout.



Second Ethylene Plant to Use Kellogg Pyrolysis Process Now Going On Stream

Marking the second large scale commercial installation so far to employ Kellogg's exclusive steam pyrolysis process, a new ethylene plant is now going on stream near Milan, Italy. The plant is a part of a giant refinery modernization project Kellogg has undertaken for a well known chemicals producer. It includes a feed preparation section in which the heavy naphtha and gas oil feed stock is distilled from

crude oil, a steam pyrolysis section in which the feed is cracked at high temperatures, and a recovery section which separates ethylene and other olefin products.

Completion of the Italian plant, together with another underway in England, is indicative of a trend abroad which is expected to have more and more significance in the U. S.

Ethylene markets on both sides of the Atlantic have skyrocketed in the last few years. U. S. producers have for the most part to date concentrated on cracking gaseous feeds—principally ethane and propane recovered from natural and refinery gases.

European producers, however, motivated by a lack of sufficiently large quantities of "crack-able" gases, have found it profitable to manufacture ethylene from heavier petroleum fractions. Important as a key to this movement has been Kellogg's steam pyrolysis design, developed specifically for such feed stocks.

The significance of this development to the domestic picture stems from several facts: First, the success of Kellogg's pyrolysis process has been proved in lengthy commercial operation to have superior advantages in high yields without excess coking. Second, the same principle can be adapted to the use of such feedstocks as casinghead or natural gasoline, residuals, and other low value products which tend to be in over supply in the U. S. And third, the principle is also adaptable to conventional feeds.

For further information, technical data, etc., relating to chemical or petrochemical processing, write

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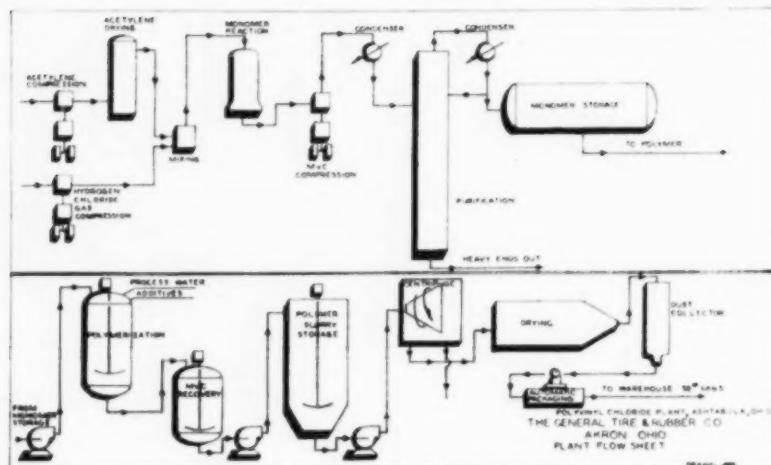
GLYCEROL

KELLOGG

new polyvinyl chloride plant

A new \$6,000,000 plant for the production of PVC resin has been put on stream at Ashtabula, Ohio, by the General Tire and Rubber Co. This makes General Tire one of the largest integrated producers of plastic film and plastic sheeting. A large share of the 25 million pounds of PVC annual capacity will supply plants at Lawrence, Mass.; Jeannette, Pa.; Toledo, Ohio; and Marion, Ohio. The processes in use at the new plant were designed and engineered by the Scientific Design Co., Inc., New York, who recently completed a similar project for one of Europe's leading chemical manufacturers. The plant will employ about 30 supervisory and administrative employees. Two major raw materials for the new plant will be piped in by neighboring industries. Electrometallurgical Division of Union Carbon & Carbide Corp. will supply acetylene and Hooker-Detrex Co. will furnish HCl. The plant will be centralized in a major industrial market area and near to railroads and main truck routes.

The accompanying aerial view shows general plant layout. Building in foreground houses the offices and the admin-



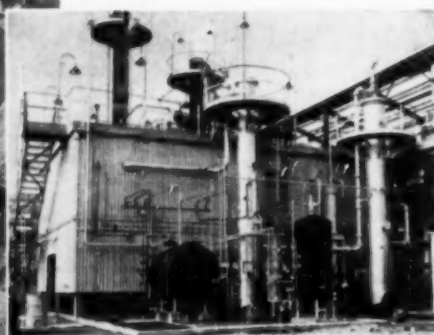
istrative staff. The four long buildings following the offices are the drying unit, laboratory, shop, and warehouse. A rotary dryer is 10' in diameter and 30' in length and uses steam as a source of heat to dry the polymer. Behind the left corner of these buildings is the boiler house.

The polymerization and storage tanks are situated behind the right corner of these four long buildings. These tanks are of 15,000 gal. capacity, receiving a slurry of water and PVC which is maintained in an agitated state, from the polymerization kettles and feeding to the dryers. They serve to link the continuous dryer with the batch PVC kettles. In the shed are ten reactor kettles containing a suspending agent (amounting to only 1%, an important advantage of the process), catalysts, water, and vinyl chloride monomer. 10% of unreacted monomer is returned to storage. The

balance proceeds to the dryer. Each kettle is jacketed and the temperature is maintained within 1° F. by a flow of water through the jackets. Working capacity of the kettles is 3500 gallons.

Adjacent to the polymerization plant is the pilot plant. Beyond the polymerization plant in the upper right corner is the monomer plant in which acetylene and hydrogen chloride are the key ingredients. The tanks are storage units for the system of scrubbing and distillation columns which purify the monomer.

Next to the boiler house in the upper left in succession are the pump house, monomer storage tanks, instrument building and compressor building. Instrumentation in the plant is extensive. A control center monitors activity in the polymerization building. Two similar centers control the monomer facilities and the boiler plant.



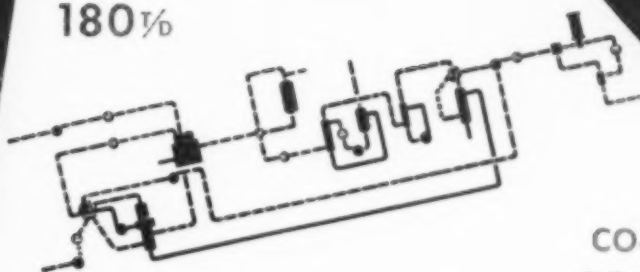
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Deere[○]
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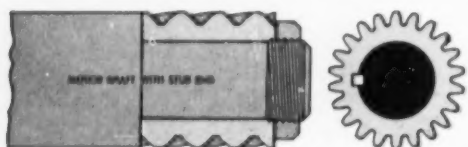
tons/day NH₃
"know how"



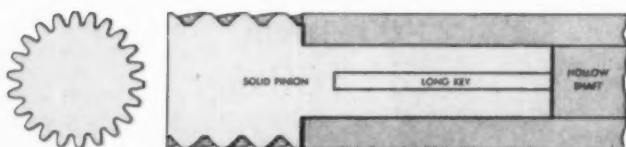
Circle 54 on Reader Service Card

In your opinion, which pinion?

... for longest life in a gearmotor



ORDINARY SHELL TYPE PINION



U. S. SOLID TYPE PINION

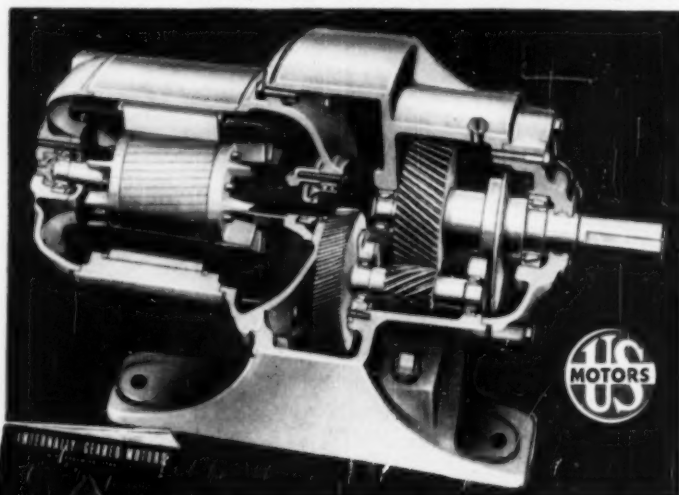
In an internally geared motor the pinion on the motor shaft is the vital link between motor and gearing. It's the fastest, but smallest gear, so it must be extra strong, free from vibration and forever tight. Now compare the U. S. Syncro-gear motor pinion with the ordinary type. Note the extra large section area of the U. S. design. It has a long solid shank that anchors into the motor's hollow shaft, whereas the ordinary shell type has a small section area, short keyed.

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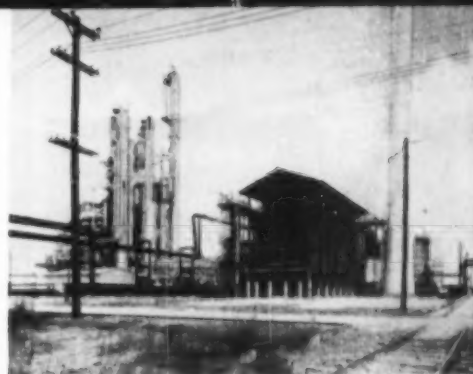
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TURBINES AND COMPRESSORS

Used in Gulf Ethylene Plant, Port Arthur, Texas

Unit Designation	Worthington Turbine Model No.	Working Medium (Turb.)	Turbine Horsepower	Steam Rate, lbs. per hour	Number and type Turbine stages	Speed RPM	Worthington Compr. Model	Stages	Substance Handled	Capacity CFM	Pressure psia.	Suction Temp. ° F.	Pressure psia.	Discharge Temp. ° F.	Horsepower
A	5.8	Steam	1,700	17,600	1 Curtis 8 Pressure	5,460	GUR 3G5	5	Charge Gas	6,660	33.7	105	102	270	1,667
B	6S	Steam	1,530	14,000	6 Pressure	8,700	GUR 3G6	6	Charge Gas	2,710	77.0	105	265	270	2,140
C	Gas Expander	Charge gas	720	28,320	1 Pressure	8,700									
D	4SQ2	Steam	5,000	47,900	6 Pressure	7,890	GUR 3G5	5	Charge Gas	2,050	254.7	105	735	231	4,760
E	6S	Steam	3,050	29,200	6 Pressure	9,140	3 E 4	4	Ethane	920	64.0	-60	275	140	2,773
F	3TV3	Steam	7,850	78,500	6 Pressure	5,800	3 F 4	4	Propane	5,230	30.5	-10	275	168	7,475

Fig. 1. General view of the Gulf ethylene plant.



centrifugal gas compressors

one of world's largest
light hydrocarbon installations
described

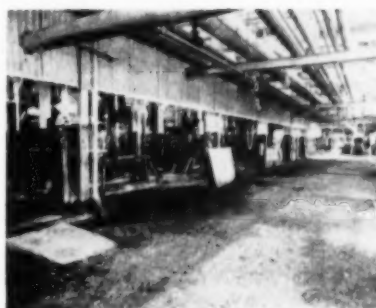
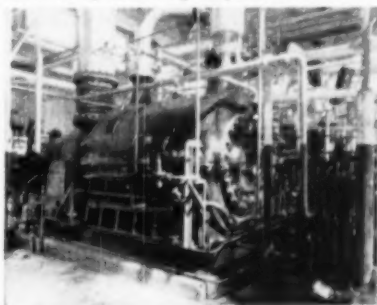


Fig. 2. Turbine end view of the building housing the turbines and compressors. Note steam supply lines.

Fig. 3. Compressor "A" which handles charge gas. Water injection nozzles prevent co-polymerization by controlling temperature.



One of the country's largest installations of turbine driven centrifugal compressors is a vital part of the new ethylene plant at the Gulf Oil Corporation's Port Arthur, Texas, refinery. This large installation, designed by the Lummus Company with compressors and turbines furnished by Worthington, is the only ethylene plant known which is delivering its products directly to consumers by pipe line. Some customers are located in the great industrial area near Houston and Texas City, which is upwards of eighty miles from Port Arthur.

This plant also is believed to be the first installation using centrifugal compressors for charge gas compression, water injection for cooling to prevent co-polymerization and multi-nozzle single-casing compressors to accommodate large bleed-in loads at pressure between initial suction and final discharge levels.

Five Worthington steam turbines and one gas expander provide a total of 19,850 horsepower to turn the five centrifugal compressors. Rotative speeds range from 5460 to 9140 rev./min.

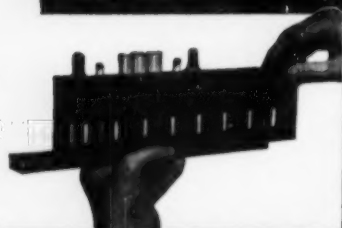
Fundamentally, the purpose of the plant is to fractionate a mixture of refinery gases (by-products from other

(Continued on page 60)



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1954 award winners



J. R. Bowman

E. R. Gilliland

E. R. Gilliland, Professor of Chemical Engineering at M.I.T., and J. R. Bowman, Director of Research at the Mellon Institute for Industrial Research, were the 1954 recipients of the Institute's Annual Awards presented at the Awards

Banquet on December 14 in the Hotel Statler, New York. C. G. Kirkbride, president of the Institute, presented Dr. Gilliland with the William H. Walker Award, and Dr. Bowman with the Professional Progress Award.

Professional Progress Award

The Professional Progress Award is made each year to a chemical engineer under forty-five years of age "to recognize outstanding progress in the field of chemical engineering, for the betterment of human relations and circumstances." The Award is sponsored by the Celanese Corporation of America and carries with it a prize of \$1,000.

The citation reads—"To John R. Bowman in recognition of distinguished services to the science and profession of chemical engineering by bringing to it skills of other scientific and mathematical disciplines and by showing how these powerful tools can be put to work in the solution of chemical engineering problems."

Dr. Bowman, now active in the field of digital computing machinery, has electronics as another major interest. He has specialized in theoretical research in the physical sciences, especially in chemical engineering and physical chemistry. He has presented numerous talks before professional organizations about distillation theory, particularly under high vacuum, chemical constitution of petroleum, the physical properties of waxes, fractional crystallization, mass spectrometry, gaseous diffusion, and combustion. He has written many papers for technical journals on these topics, and holds several patents in these fields.

A native of New York City, Dr. Bowman received his B.S. degree in 1929 and his Doctorate in 1934, both from the University of Pittsburgh. He is active in the work of many professional organizations including A.I.Ch.E.,

(Continued on page 71)

William H. Walker Award

The William A. Walker Award, given to honor the memory of the late William H. Walker, who was a professor at M.I.T. and a pioneer in the modern concept of chemical engineering, is provided to encourage excellence in contributions to chemical engineering literature.

Professor Gilliland, an authority on separation processes and applied industrial chemistry, has been given this recognition because of his publication record over the past few years and in particular for four papers contributed to Chemical Engineering Progress. The topics covered were fugacity, gasification and the mechanics of drops.

Born in Oklahoma, Dr. Gilliland received his B.S. in Chemical Engineering from the University of Illinois; M.S. in Chemical Engineering from Pennsylvania State College; and an Sc.D. in Chemical Engineering from M.I.T. He also holds an honorary degree of Doctor of Engineering from Northeastern University. Professor Gilliland has been associated with M.I.T. since 1934 as an educator. He has acted as Deputy Dean of Engineering at M.I.T., Chairman of the Faculty, and Acting Head, Dept. of Chemical Engineering.

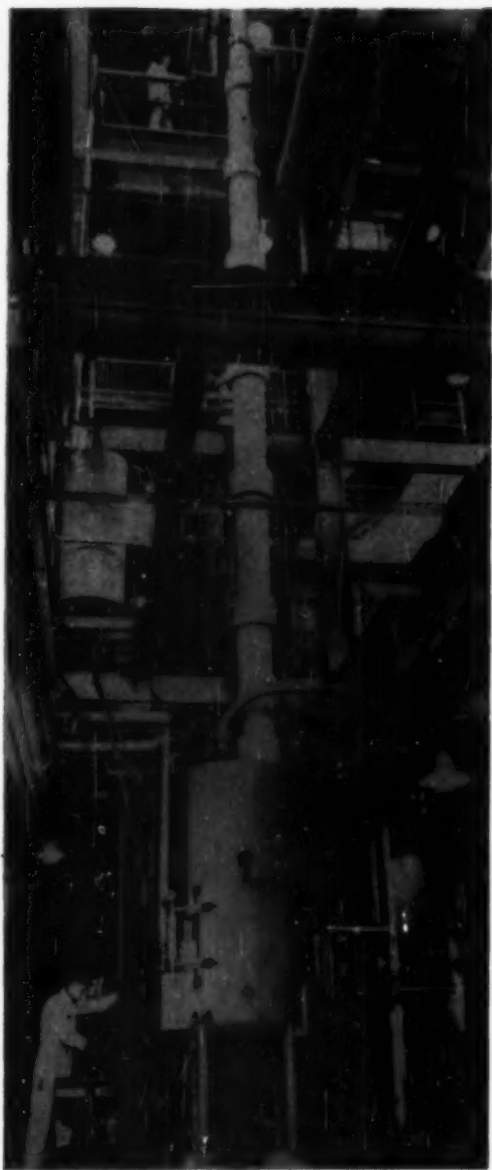
Active in Government work, he has served as Asst. Rubber Director in charge of Research and Development, Office of the Rubber Director; the Guided Missiles Committee; Fuels and Lubricants Committee; Jet Propulsion Panel; and as a Consultant to Brookhaven National Laboratory.

He has acted as consultant to industrial companies in the fields of heavy

(Continued on page 71)

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increases column throughput
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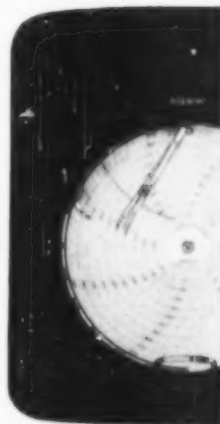


Heat input to the still of this vacuum packed fractionating column in Dow Corning pilot plant is under precise Foxboro Control. Based on pressure drop across column, Foxboro Control maintains optimum conditions at all times. See diagram.

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of pressure drop

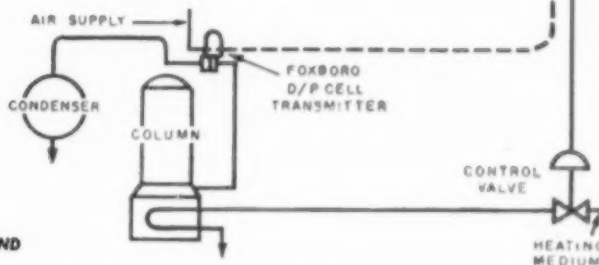


Maximum column loading with minimum priming or carry-over is one outstanding efficiency feature of Dow Corning Corporation's pilot plant production of chlorosilanes and silicones at Midland, Mich. To achieve this optimum throughput, completely unaffected by variations in product concentration, Dow chemists employed the Foxboro Pressure Drop Method of Control.

In this automatic Foxboro System, a d/p Cell Transmitter continuously measures column pressure loss caused by plate or packing resistance plus liquid and vapor mass velocities. This true measure of vapor product movement is relayed by the transmitter to a Foxboro M/40 Controller. The Controller precisely regulates heat input to the column . . . maintains steady boil-up for any given feed stock, without overloading.

Foxboro Pressure Drop Control will perform with the same high-efficiency on your column . . . whether it's packed, bubble cap, or sieve-plate type . . . on continuous or batch runs. For complete details, write for Engineering Data Sheet 282-14.

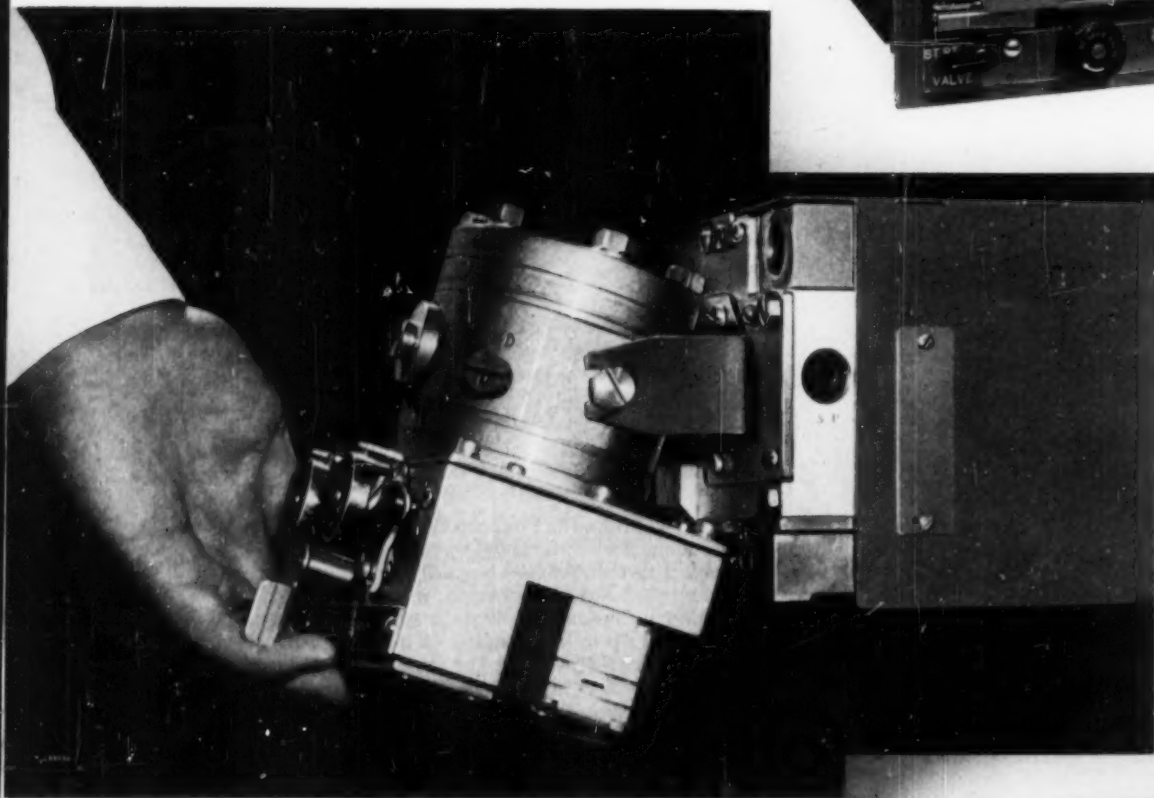
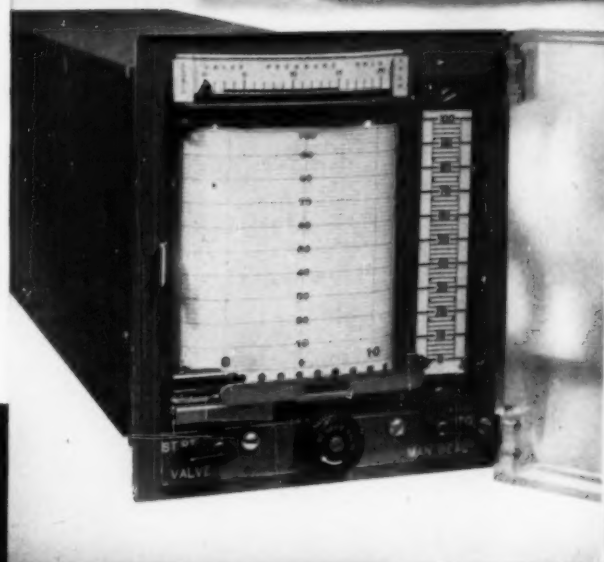
The Foxboro Company, 9312 Neponset Ave.,
Foxboro, Massachusetts, U.S.A.



automatic control for
fractionating column pressure-drop

Horizontal scale above chart provides continuous indication of control air pressure to valve. ▶

Quick-connect controller mounting . . . for added protection the controller is supported by a yoke when disconnected.



All adjustments are readily accessible from the rear of the controller. ▶



◀ *Unitized construction of all major components simplifies maintenance . . . makes re-assembly foolproof.*

Today's

Tel-O-Set*

instruments

are easiest

to install

... operate

... service

THE latest improvements in the *Tel-O-Set* family of miniature recorders and controllers make them the simplest and most convenient ever. Operating men, installers and service men alike will appreciate these outstanding features:

Quick-connect mounting—either on back of recorder, back of panel, or at a remote location. A single lever opens or closes all interconnecting air lines . . . allows the controller to be removed without interfering with manual control of the process.

Foolproof connect and disconnect. The rear of the recorder is a flat gasketed surface that matches up perfectly with the controller. It's completely free of any protruding valve stems or plug-in fittings that might be damaged in shipping or handling in your plant. Self-contained air switch must be shut off before the controller can be removed.

Leakproof design—with large capacity valves.

Wide range of reset rates. A single instrument provides a simple choice of three different ranges . . . fast, intermediate and slow . . . enabling one basic model to serve in applications formerly requiring several models.

Versatility. Rate action is readily added. When equipped with a manifold, the controller can be mounted remotely, either back of the panel or in the field.

Low air consumption—less than 0.2 scfm.

Unitized construction—permits fast, easy removal and replacement of major sections.

Compare the features . . . and the operating characteristics . . . of the *Tel-O-Set* line of instruments. You'll find they represent the top in value in miniature instrumentation, that will give you the top in performance and serviceability on your process control panels. For a discussion of your specific requirements, call your nearby Honeywell sales engineer . . . he's as near to you as your phone.

MINNEAPOLIS-HONEYWELL REGULATOR CO.,
Industrial Division, Wayne and Windrim
Avenues, Philadelphia 44, Pa.

• **REFERENCE DATA:** Write for your copy of new Bulletin No. 7201,
"Quick-Connect *Tel-O-Set* Instruments."

**Tel-O-Set* is a trade mark of the Minneapolis-Honeywell Regulator Co.



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Honeywell
BROWN INSTRUMENTS

First in Controls

ON STREAM

ON TIME

ON BUDGET

ON THE WABASH

By the banks of the Wabash River at Robinson, Illinois, this new 8,330 barrel-per-day Hou-driforner of the Ohio O'l Company is on stream, producing a high yield of superior quality gasoline from naphtha charge stocks. The new catalytic reforming unit is equipped with three catalytic reactors, a guard reactor and a three-stage heater.

Engineered and constructed by the Catalytic Construction Company, it was completed on schedule. The actual cost was below the original estimate.

CATALYTIC ON-TIME . . .

ON-BUDGET SERVICES

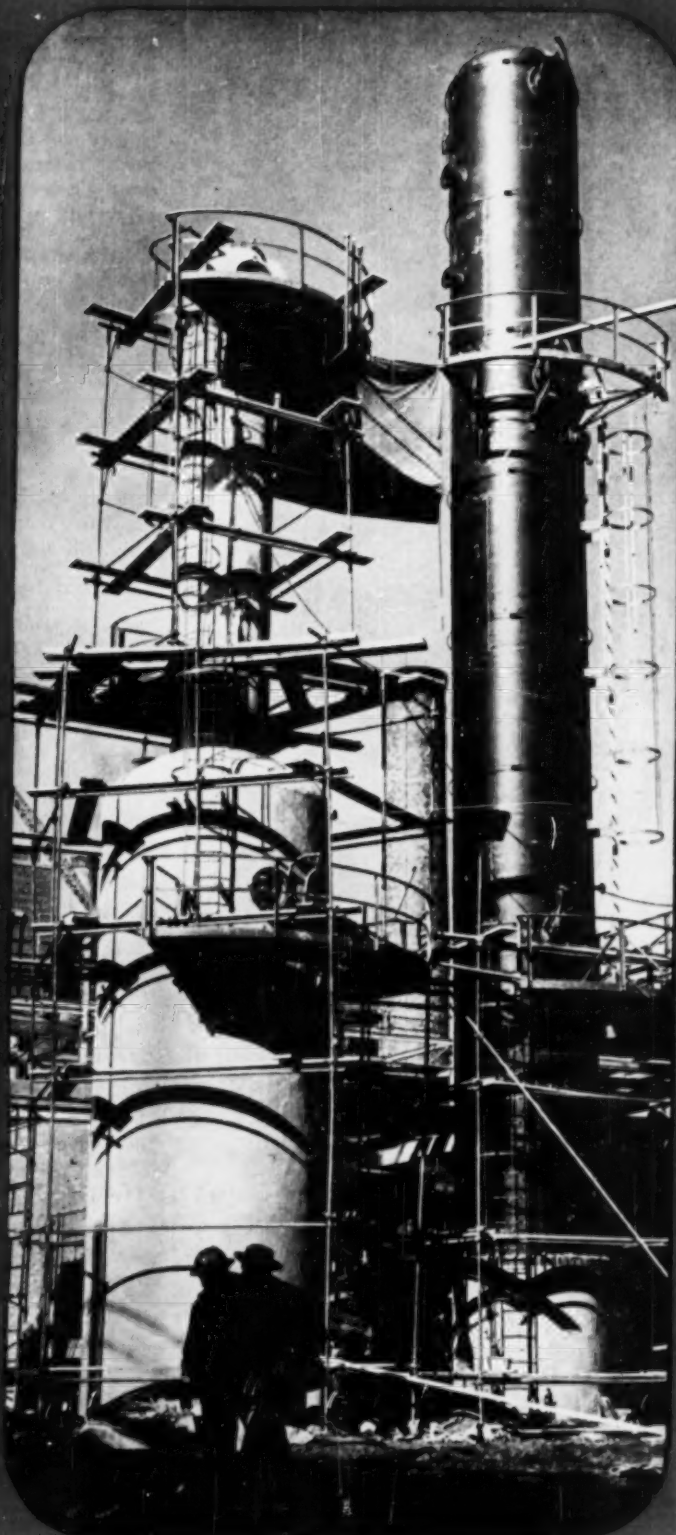
for the atomic energy, chemical, petrochemical and oil refining industries • Project Analysis • Process Design • Economic Studies • Engineering • Procurement • Construction • Plant Operation

CATALYTIC CONSTRUCTION COMPANY

1528 WALNUT STREET
PHILADELPHIA 2, PA.

In Canada:

Catalytic Construction of Canada, Limited
Sarnia, Ontario



We create a **CYCLONE**

to give you

DRIER Compressed Air

with R. P. ADAMS Separators

THAT'S right! Through a unique engineering design, we create a cyclone with the Adams separator to remove more moisture from your compressed air. That is why, when combined with an efficient Adams Aftercooler, the separator is highly effective . . . even when passing small volumes of air.

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R. P. ADAMS Co., Inc.

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R. P. ADAMS CO., INC.
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Buffalo 17, N. Y.

Please send my FREE copy of Bulletin #177 on Adams Cyclone Separators and Aftercoolers.

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Street _____

City _____

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NEWS from FILTERTOWN

A boon to the filtration of beer is the successful development by the E&D laboratories of a new, high wet strength filter paper that is 25 times stronger than most any filter paper ever known. Yet, it is sufficiently porous to permit the rapid filtration of as many as 150 barrels per hour. BREW-BRITE (registered name) effects tremendous savings in time and money. And the brewmasters are delighted with the "high polish" obtained with it so essential for today's modern beer . . . A new, disposable cigarette filter tip, using E&D filter paper, grade 613, is gaining popularity . . . Great publicity achieved by E&D's "no-rattle" paper grade 914, used by radio and TV announcers and actors, which eliminates the bothersome sounds made by ordinary paper . . .

T. J. Druding, sales manager, announces enthusiastic acceptance of Filtration Analysis Report, designed to help industry with solution of specific filtration problems. If you would like to determine if filter paper can be of help to you, and how it will work on your filter press, with the great savings that filter paper can show over any other filter media, write for a free copy of Filtration Analysis Report or for free samples of filter paper . . . Not generally known is the fact that E&D was established in 1890; that E&D pioneered in folded filter circles; and that it is the only company in America exclusively devoted to the making of filter papers for science and industry . . . Formula for savings:

Cost of filter paper in relation to cost of filtration is .0001 or less!



**THE
EATON-DIKEMAN CO.**
FILTERTOWN
MOUNT HOLLY SPRINGS, PA.

CANDIDATES FOR MEMBERSHIP IN A. I. Ch. E.

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions.

These names are listed in accordance with Article III, Section 8, of the Constitution of A.I.Ch.E.

Objections to the election of any of these candidates from Members will receive careful consideration if received before January 15, 1955, at the Office of the Secretary, A.I.Ch.E., 25 West 45th Street, New York 36, N. Y.

Member

Addams, Hallett B., Niagara Falls, N. Y.
Aroyan, Harry J., Richmond, Calif.
Bareis, David W., Whittier, Calif.
Barkelew, Chandler H., Emeryville, Calif.
Beachley, Elmer T., Cumberland, Md.
Brown, John R., Jr., Kansas City, Mo.
Corwin, Harold E., Syracuse, N. Y.
Crabtree, Royale R., Salem, Neb.
Dailey, K. G., Melrose Park, Pa.
Dewey, John L., Madison, N. J.
Graham, James C., Ferguson, Mo.
Greenhalgh, R. E., Midland, Mich.
Grimble, Robert W., Wilmington, Del.
Guyman, Ralph H., Oak Ridge, Tenn.
Henderson, Charles D., Beaver Falls, Pa.
Irish, Donald B., Highland Park, N. J.
Jackson, Thomas M., Jr., New York, N. Y.
Larson, Robert J., Decatur, Ala.
Maloy, Arthur L., Charleston, W. Va.
McIntosh, Joseph K., Zeeland, Mich.
Molique, Lawrence G., Bartlesville, Okla.
Needles, James W., Plainfield, N. J.
Oleson, A. Paul, Argo, Ill.
Phillips, Roy, Nitro, W. Va.
Rich, Wilson C., Jr., Mountainside, N. J.
Throdahl, Monte C., Ladue, Mo.
Weaver, James B., Wilmington, Del.
Weldin, Thomas D., Calumet City, Ill.
Wilson, Stanley F., North Haven, Conn.

Associate

Andersen, L. Bryce, Bethlehem, Pa.
Apellaniz, J., Chicago, Ill.
Arnold, Clifford E., St. Albans, W. Va.
Barnwell, William A., Jr., Lake Jackson, Tex.
Barton, Robert W., Chicago, Ill.
Beutler, John A., Jr., New Castle, Del.
Bowman, E. Dexter, Jr., Denver, Colo.
Brown, William O., Houston, Tex.
Calderbank, P. H., Toronto, Ont., Can.
Carlberg, George, Beaver, Pa.
Cerro, Vincent, Pittsburgh, Pa.
Conn, Claude B., Jr., Greenville, Ala.
Cox, Charles D., Bangor, Me.
Craig, Herbert W., Larchmont, N. Y.
Currie, Peter L., Kearny, N. J.
Deis, Louis P., Westtown, Pa.
Dumas, Menelaos, Hudson Heights, N. J.
Ewing, Eugene C., Beaumont, Tex.
Farell, Jack L., South Bend, Ind.
Fisher, Donald L., Racine, Wis.
Fisher, Warren C., Lewiston, N. Y.
Gibson, Andrew G., South Charleston, W. Va.

Ginwala, Kymus, Boston, Mass.
Gould, Donald E., Bound Brook, N. J.
Grimes, M. E., Ottawa, Ont., Can.
Hansen, Paul E., St. Paul, Minn.
Haskell, Colwyn F., Orono, Me.
Hauser, W. Rex, Litchfield, Ill.
Henderson, K. D., Montreal, Que., Can.
Herrmann, Robert H., Baltimore, Md.
Holman, Donald G., Wyandotte, Mich.
Hubacek, Jerry E., Chicago, Ill.
Humphrey, M. H., Akron, Ohio
Jones, O. C., La Marque, Tex.
Koop, Rodney D., Seattle, Wash.
Kudro, Thomas G., Texas City, Tex.
Landwehr, Joseph C., El Dorado, Ark.
Lieber, Richard M., St. Louis, Mo.
Lieberman, Erwin P., Louisville, Ky.
Lovell, John A., Akron, Ohio
Lucas, William R., Philadelphia, Pa.
Mann, Bernard, Louisville, Ky.
Marocco, Frank J., Tuckahoe, N. Y.
McAndrews, John I., Cincinnati, Ohio
McNair, W. T., Robstown, Tex.
McPherson, Roland A., Jr., Akron, Ohio
Meyerand, Robert P., Alma, Mich.
Miller, Lawrence O., New Orleans, La.
Monahan, Hugh, Jr., Havre de Grace, Md.
Moss, John G., Bradenton, Fla.
Parrish, Roger W., Independence, Mo.
Petersen, Eugene E., Berkeley, Calif.
Puyear, Robert B., Malden, Mo.
Radway, Jerrold, Indianapolis, Ind.
Ragsdale, Ralph, Houston, Tex.
Rawlings, Herbert L., Nitro, W. Va.
Riggs, Donald E., St. Louis, Mo.
Smith, Ronald E., Gary, Ind.
Sovereign, Eugene F., Riverside, Ill.
Stollings, Pat A., Houston, Tex.
Thomas, Ralph I., Cresco, Pa.
Thomson, James E., Alton, Ill.
Trapane, Thomas S., Baltimore, Md.
Travelstead, Jack G., Louisville, Ky.
Van Valkenburgh, Waldo A., Jr., Upper Montclair, N. J.
Wallis, Frank J., Newark, Del.
Weinstein, Norman J., Corvallis, Ore.
Whitcomb, M. Glenn, Baytown, Tex.
Wixson, Burton R., Kenmore, N. Y.
Woomer, Warren J., Charleston, W. Va.
Yardumian, Louis H., Jr., Philadelphia, Pa.
Zurcher, Burton, Hillsboro, Ore.

Affiliate

Napier, Taylor D., Knoxville, Tenn.
Walters, Charles C., Pearl River, N. Y.

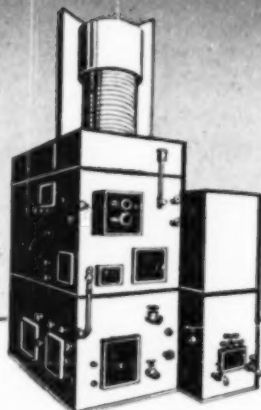
5000° F



Silicon Carbide Plant



Radiant Furnace



Air Fractionation Plant

-340° F

Blaw-Knox Chemical Plants Division
has executed
many successful projects
involving temperature levels from

-340° to 5000° F

A few representative projects include: plants for producing silicon carbide and dry ice — for low temperature fractionation to yield oxygen, nitrogen, argon, hydrogen and ethane . . . heat transfer systems using Dowtherm, Aroclors and liquid metals . . . equipment such as the radiant fired kettle.

Blaw-Knox engineers and scientists will design and build your project operating at any temperature level within a wide range.

Put this experience to work.
Call upon Blaw-Knox.

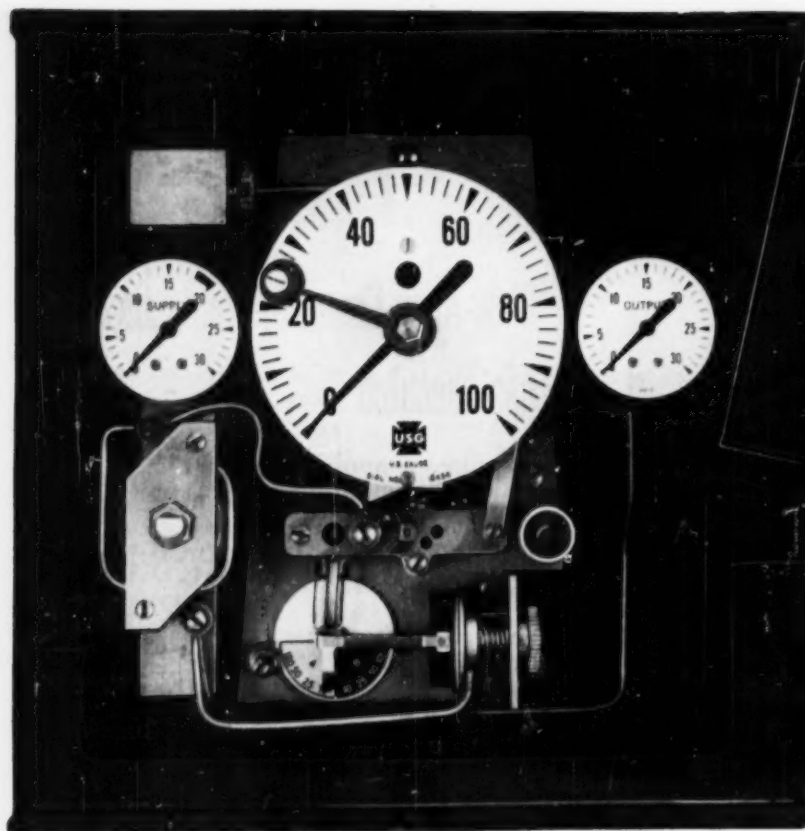
BLAW-KNOX COMPANY

CHEMICAL PLANTS DIVISION

Pittsburgh 22, Pennsylvania

Chicago 1, Illinois / Tulsa 1, Oklahoma





announcing the *NEW* HAMMEL-DAHL PRESSURE PILOT

DESIGNED and MANUFACTURED
By **U. S. GAUGE**—With all the
skill gained through years of
instrument manufacture.
For **HAMMEL-DAHL**—To
specifications that only years
of experience in control valve
applications could
formulate.

COMPLETE
Information in
Bulletin 110

Compare These Features

- Integral gauge for controlled pressure indication.
- Direct setting of control point on calibrated dial.
- Screwdriver adjustment for:
 - (1) PROPORTIONAL CONTROL
 - (2) DIFFERENTIAL GAP
 - (3) EASY REVERSAL OF ACTION
- Sapphire nozzle feed orifice with push button cleaner.
- All metal power relay and modern feedback action.

HAMMEL-DAHL COMPANY



175 POST ROAD, (WARWICK) PROVIDENCE 5, R. I., U. S. A.



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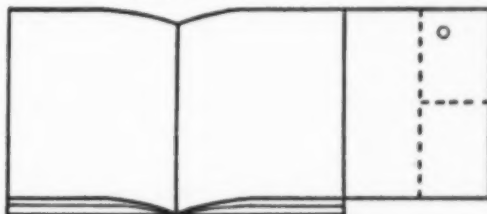
MANUFACTURING PLANTS IN WARWICK, R. I., U. S. A., CANADA, ENGLAND, FRANCE AND HOLLAND

CANADIAN MANUFACTURING AFFILIATE—GUELPH ENGINEERING CO., GUELPH, ONT.

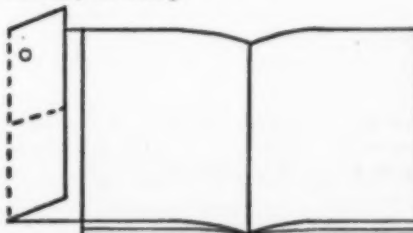
for your information

This C.E.P. information service is a convenient way to get the chemical engineering information you need on the new equipment, on advertised products, on the newly announced developments reported on these pages. A one post card inquiry designed to bring data quickly and easily. Circle the items of interest, sign your name, position, address, etc., and drop in the mail.

Just a moment is needed to learn how to use this insert. When looking through the front part of the magazine pull the folded portion of the insert out to the right, and the numbers on the post card are convenient for marking. THEN



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New York



PRODUCTS

- IFC Steam Tube Dryer.** From pilot plant size to largest built a right size for your job. Recommendations are job-tested. Louisville Drying Machinery Unit, General Transportation Corp.
- 3R Barrel & Drum Packer.** Packs more material in smaller, low-cost containers. Capacities to 1,000 lb. Models for bags to 150 lb. B. F. Gump Co.
- 4L Diatomite Filter System.** Stop water waste by reuse of water purified by use of diatomite filter. Sparkler Mfg. Co.
- 5A Steam Trap.** Feature less parts & more capacity. 2 to 6 times average drainage capacity. W. H. Nicholson & Co.
- 6A Impervious Graphite Process Equipment.** Karbate process equipment & National carbon & graphite structural shapes for ruggedness & corrosion resistance. National Carbon Co.
- 8A Porcelain Valves.** Resistance to chemicals, uniform quality, high mechanical strength result from use of solid porcelain valves. Lepp Insulator Co., Inc.
- 9A Pulsefeeder.** Hard to pump fluids successfully handled with Pulsefeeder a piston-diaphragm, controlled volume pump. Lepp Insulator Co., Inc., Process Equipment Div.
- 10L Extruded or Molded Rods, Tubes, Special Shapes.** Fabricated of chemically inert Teflon, resist heat & cold, nonadhesive. Ethylene Chemical Corp.
- 11A Centrifugals.** Materials with dissimilar filtering & washing characteristics easily processed using "all-speed" drive. Tolhurst Centrifugals Div., American Machine and Metals, Inc.
- 12A Valves.** Heavy-duty, all-iron valves to 300 lb. for use with ammonia, air, oil, gas, & caustic in process work. Crane Co.
- 13A Plastic Pipe.** Dur-Ace pipe fabricated from corrosion resistant plastic has exceptional impact & strength. American Hard Rubber Co.
- 14L Shaft Seal.** Fabricated from chemically impervious Teflon in balance bellows design Chemiseal external mechanical seals. United States Gasket Co.
- 15A Fertilizer.** Crystalline ammonium nitrate fertilizer in one simple step with Stengel process now available on license. The Chemical and Industrial Corp.
- 16A Celite Filtration.** Use of Celite filter cake removes finest suspended solids. Contains 2,500,000 filter channels/sq. in. of surface. Johns-Manville
- 17A Tubular Products.** Seamless, welded stainless steel, and welded carbon steel tubing. The Babcock & Wilcox Co.
- 18A Laminated Polyester Glass.** Cooling towers & other structures subject to corrosive liquids & gases respond to construction with this material. Haveg Corp.
- 19A Mixers.** Uniformly blends special vinyl compounds. Capacity 50 to 75 gal. Stainless #304 trough shell, jacketed for 80 lb. steam pressure. Baker Perkins, Inc.
- 20A Furnaces.** Economic melting & casting using vacuum furnace. Units for processing to 2,000 lb. high-purity metals. F. J. Stokes Machine Co.
- 21A Alternate Heating & Cooling.** Use of Dowtherm provides to 750° heat. Equally valuable as a coolant. Absorbs heat at high temperatures. The Dow Chemical Co.
- 22L Filters.** Continuous flow of filtrate accomplished by using battery of two or more. R. P. Adams Co., Inc.
- 24A Steel Belt Conveyors.** Patented water-bed conveyor makes processing more automatic. Water pressure assures 100% coolant contact with belt. Sandvik Steel Belt Conveyors Div. Sandvik Steel, Inc.
- 25A Dissolved Oxygen Analyzer.** Unit permits accurate measurement of dissolved oxygen in process streams. Arnold O. Beckman, Inc.
- 26A Vacuum Filters.** Prevents cake cracking, improves washing & on some filter cake reduces moisture content by 8 to 10%. The Elmco Corp.
- 27A Plant Construction.** Engineering & construction of petroleum, chemical & power plants. The Lummus Co.
- 28L Process Equipment.** Distillation using boiling plates & trays designed by specialists in the field. Badger Mfg. Co.
- 29R Heat Exchangers.** Manufacture of customer or company design equipment. Illustration shows example used at subzero temperatures. Badger Mfg. Co.
- 30A Hydraulic Pump.** Air-driven for small volume capacity at low or high pressures. Self-contained. The Aldrich Pump Co.
- 31A Carbon Dioxide Removal.** Processes & plants; processing apparatus designed & built. The Girdler Company.
- 32A Proportioning Pumps.** From stock & ready to solve chemical proportioning problems. Self-contained & ready to operate. Proportioners Div. of B-I-F Industries, Inc.
- 386A Intalox Saddles.** Higher flooding limits of these saddles aid in increasing capacity 30%. Patented shape. The United States Stoneware Co.
- 35A Process News.** Second ethylene plant using Kellogg pyrolysis process now going on stream. Information on chemical or petroleum processing. The M. W. Kellogg Co.
- 37A NH₃.** Are you interested in "know how"? Then write for the "know how" bulletin on NH₃. Foster Wheeler Corp.
- 38A Syncrogear.** Because it's small & fast it must be extra strong, free from vibration, & extra tight. Gears are deep-hardened & shaved to exact tolerances. U. S. Electrical Motors, Inc.
- 40L pH, Chlorine Tests.** Fast, accurate, easy tests made in three simple steps in seconds. W. A. Taylor and Co.
- 41A Pressure-drop Control.** Maximum column loading with minimum priming or carryover using d/p cell transmitter. Column may be packed, bubble-cap, or sieve-plate. The Foxboro Co.
- 42A Miniature Recorders & Controllers.** Feature quick-connect mounting, foolproof connect & disconnect, low air consumption. Minneapolis-Honeywell Regulator Co.
- 44A Houdriformer.** Now on stream an 8,330 bbl./day unit for production of gasoline from naphtha charge stocks. Catalytic Construction Co.
- 45A Cyclone Separators & Aftercoolers.** Effective even in passing small volumes of air. R. P. Adams Co., Inc.
- 46L Filter Paper.** High wet strength filter paper permits rapid filtration to 150 bbl./hr. The Eaton-Dikeman Co.

Chemical Engineering Progress

Numbers followed by letters indicate advertisements, the number corresponding to the page carrying the ad. This is for ease in making an inquiry as you read the advertisements. Letters indicate position—L, left; R, right; T, top; B, bottom; A indicates a full page; IFC, IBC, and OBC are cover advertisements.

Be sure to give name, address, position, etc.

Remember, the numbers on the upper portion of the card bring you data on only the bulletins, equipment, services, and chemicals reported in these information insert pages. The lower portion of the card is for the advertised products, and is keyed not only to advertising pages, but also to the memory-tickling list under the heading Products.

- 47A **Chemical Plants.** Staff of engineers & scientists available for projects operating at any temperature level over wide range. Blaw-Knox Co., Chemical Plants Div.
- 48A **Gauge.** Features controlled pressure indication, screw-driver adjustment on control, differential gap, action reversal. Hammel-Dahl Co.
- 53A **Blenders.** A p-K blender for every dry mixing operation The Patterson-Kelley Co., Inc.
- 57A **Caustic Soda.** A base chemical in manufacture of soaps. Graphite anodes basic in electrolytic industry meet need for chlorine & caustic. Great Lakes Carbon Corp., Electrode Div.
- 59A **Dryers & Calciners.** For experiment & development laboratories to determine chemical & physical aspects of a heat processing project in advance. The C. O. Bartlett & Snow Co.
- 60L **Double Cone Blender.** Ten outstanding features listed. Include steel supports, special control & brake, oil-operated valve. General Machine Co. of New Jersey
- 61A **Castings, Valves, Fittings, Accessories.** Made of stainless steel & corrosion resistant. Cooper Alloy Corp.
- 62B **Heat Exchangers.** Designed, built, & installed for process refinery & power plant application. Sizes 1 sq.ft. to 45,000 sq.ft. heat transfer surface. Condenser Service & Engineering Co., Inc.
- 63A **Water Supply.** Plant site 50 to 3,000 acres in size with water capacities from 10 million gal. to 37 billion gal./day. St. Louis-San Francisco Railway.

(Continued on back of this insert)

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Advertisers' Products

IFC	3R	4L	5A	6A	8A	9A	10L	11A
12A	13A	14L	15A	16A	17A	18A	19A	20A
21A	22L	24A	25A	26A	27A	28L	29R	30A
31A	32A	586A	35A	37A	38A	40L	41A	42A
44A	45A	46L	47A	48A	53A	57A	59A	60L
61A	62B	63A	64L	65A	66L	67A	68B	69A
70L	71R	72L	72R	73R	74B	75R	76L	77R
79R	80L	80R	81R	83R	85R	86L	86R	87T
87B	88T	88B	89R	90L	91T	91BL	91BR	94T
94B	95B	IBC	OBC					

Chemical Engineering Progress Data Service

Name
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 Company
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 City Zone State

☐ I want a subscription. Bill me \$6.00 for a year.

December, 1954

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86	87	88	89	90	91	92	93	94	95	96	97	98
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114	115	116	117	118	119	120	121	122	123	124	125	126
127	128											

Advertisers' Products

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12A	13A	14L	15A	16A	17A	18A	19A	20A
21A	22L	24A	25A	26A	27A	28L	29R	30A
31A	32A	586A	35A	37A	38A	40L	41A	42A
44A	45A	46L	47A	48A	53A	57A	59A	60L
61A	62B	63A	64L	65A	66L	67A	68B	69A
70L	71R	72L	72R	73R	74B	75R	76L	77R
79R	80L	80R	81R	83R	85R	86L	86R	87T
87B	88T	88B	89R	90L	91T	91BL	91BR	94T
94B	95B	IBC	OBC					

Chemical Engineering Progress Data Service

Name
 Position
 Company
 Address
 City Zone State

☐ I want a subscription. Bill me \$6.00 for a year.

December, 1954

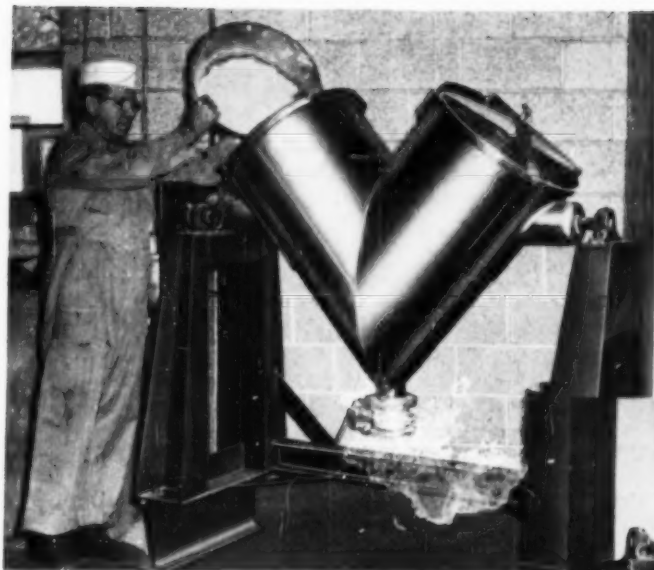
PRODUCTS (Continued)

- 64L **Wire Cloth & Metal Parts.** Wire cloth & metal parts fabricated to special order. Newark Wire Cloth Co.
- 65A **Dual Projects.** Now you may have your old equipment renewed while an entirely new process unit goes in. Badger Mfg. Co.
- 66L **Diaphragm Valve.** Body of valve fabricated from Uscolite a chemically resistant material. Sizes 1/2 to 2 in. Hills-McCanna Co.
- 67A **Pyrex Pipe.** Protection from metallic contamination assured sensitive chemicals. Easy to clean & transparent. Corning Glass Works.
- 68B **Reaction Flasks.** Feature heads interchangeable with bottoms. Have large necks for easy cleaning; one clamp fits all capacities. Ace Glass, Inc.
- 69A **Insulation.** Have you an insulation problem? If so, write for information about Weather-Protected Insulation. Johns-Manville.
- 70L **Heat Exchanger.** Aero cools liquids & gases by evaporative cooling with atmospheric air. Saves cost of cooling water. Niagara Blower Co.
- 71R **Rubberhite Linings.** Long-lasting protection for metal products, parts, & equipment, any size or shape, coated inside or out. Goodall Rubber Co.
- 72L **Transmissions.** Select-O-Speed used to drive & control, for use on vibrator pulley & shaft. Ratios 10 to 1. Lovejoy Flexible Coupling Co.
- 72R **Heat Exchangers.** Pilot plant or special requirements handled by staff. Variety of equipment for process industries. Davis Engineering Corp.
- 73R **Valves.** Type F valve for use on 66° B_e sulfuric acid service. Sizes 1/4 through 2 in. The Durlin Co., Inc.
- 74B **Florite Desiccant.** Economical granular drying agent giving low dew point depression plus good resistance to poisoning effects. Floridin Co.
- 75R **Process Plants.** Specializing in plants for: fats and oils, fatty alcohols, resins, soaps & detergents, etc. Industrial Process Engineers.
- 76L **Tantalum.** May be used advantageously for most acid solutions, corrosive gases or vapors except HF, alkalies or materials with free SO₂ content. Fansteel Metallurgical Corp.
- 77R **Hard Rubber Pumps, Valves, Fittings.** Buna N & natural hard rubber pumps, globe, angle & Y valves. Also pipe & fittings. Vanton Pump & Equipment Corp.
- 79R **Centrifugal Castings.** Duraspun screw conveyor an example of unusual castings produced in centrifugal castings department. The Duraloy Co.
- 80L **Vitreosil Tubing.** Available in either transparent, glazed, sand or satin surfaces. Sizes to 32 mm. bore; opaque to 4 1/2 in. The Thermal Syndicate Ltd.
- 80R **Pie-Tank Stacks.** Lightweight, easily-erected stacks, 44 in. diam., 69 ft. long, 90° elbow. Prefabricated. The Chemical Corp.
- 81R **Teflon Packing.** Lattice Braid Teflon packing unaffected by solvents. Retains square shape. Does not extrude. The Garlock Packing Co.
- 83R **Chlorination.** Heat exchange plus slime control problems minimized. Wallace & Tiernan Co., Inc.
- 85R **Heat Exchangers.** Custom-built units available at standard unit prices. Delivery two to three weeks. Downingtown Iron Works, Inc.
- 86L **Photochemical Equipment.** Ultraviolet radiation source of actinically sensitized high-pressure reactions. Produces more in less time. Hanovia Chemical & Mfg. Co.
- 86R **Ion Exchange.** For chemically-pure water, & to eliminate all dissolved solids. Illinois Water Treatment Co.
- 87T **Portable Mixer.** Easy-to-mount mixers in sizes 1/20th to 7 1/2 hp. simplifies small batch mixing. Alsop Engineering Corp.
- 87B **Spraco Nozzles.** Complete catalog available. Full cone, flat spray, & hollow cone nozzles. Spray Engineering Co.
- 88T **Process Piping.** Fabricated from complete range of alloys, diameters to 60 in., any shape. The Pressed Steel Co.
- 88B **Meters.** For pressures to 500 lb./sq.in. Xacto meters for liquid measurement. Sizes 15 & 50 gal./min. with 1 1/4 & 1 1/2 in. connections. Bowser, Inc.
- 89R **Gyrotor.** Use results in extremely close product control in dry grinding or separating operations. Hardinge Co., Inc.
- 90L **Antifoam.** 3 grams kill foam in 10 tons of asphalt or alkyd resin. Dow Corning Corp.
- 91T **Airchek Valve.** Reduces discharge line noise. Safe because it eliminates human element. Automatic. Pennsylvania Pump and Compressor Co.
- 91BL **Research Program.** Research programs, small or large. Every available facility. Foster D. Snell, Inc.
- 91BR **Alloys.** Stainless steel, Monel, Inconel, nickel & aluminum process equipment. Alloy Fabricators Div. of Continental Copper and Steel Industries, Inc.
- 94T **Bonate Stacks.** Lightweight, self-supporting stacks 80 ft. high & 5 1/2 ft. wide, economically solve problem of fumes & corrosion-laden atmosphere. Beetle Plastics Corp.
- 94B **Filters.** Useful ideas & developments on filtration methods, equipment, & fluids handling, available in Filter Facts. T. Shriver & Co., Inc.
- 95B **Evaporator Units.** Dependable vacuum supplies pure, potent pharmaceutical products. Also available are jet mixers, heaters, absorbers, pumps. Croll-Reynolds Co., Inc.
- IBC **Tanks.** Special purpose equipment available. Also standard units in alloy, copper, steel fabrication. The Vulcan Copper & Supply Co.
- OBC **Uniform Mixing.** How to control fluid flow for rapid uniform mixing described in simple mixer flow pattern. Mixing Equipment Co., Inc.

CHEMICALS

- 1 **Glacial Methacrylic Acid.** From Rohm & Haas Co. Special Products Dept. bulletin on glacial methacrylic acid. Sections on availability, properties & specifications, polymerization, reactions, & applications.

(Continued on page 54)



Charging a **p-k** Twin Shell Blender through one of the two large access ports at O. M. Franklin Serum Co. plant in Denver, Colo.

Complete discharging through butterfly type valve.



This **p-k**
Twin Shell Dry Blender†
gives Denver livestock
supply house

*"A Thorough Mix of Dry Materials" **

"I have been in charge of various types of production, for the past fourteen or fifteen years" says Kevin M. Curyea, manager of the manufacturing division of O. M. Franklin Serum Co., "but I think this machine (a 5 cu. ft. capacity **p-k** Twin Shell Dry Blender) is one of the best buys I have ever made. It is simple to load and unload, it is efficient and fast, and it takes up a very minimum of space."

"The average time to blend our dry powders," Mr. Curyea estimates, "is from four to six minutes." And, he adds, "the machine can be cleaned up easily in five minutes."

There is a **p-k** blender that will make your dry mixing operations faster, more thorough and more efficient. Write today for full information.

*All quotations on this page are from a signed letter from Mr. Curyea to the Patterson-Kelley Company, Inc.



the **Patterson-Kelley Co., inc.**

1820 Lackawanna Avenue, East Stroudsburg, Penna.

† Patented

101 Park Avenue, New York 17 • Railway Exchange Building, Chicago 4 • 1700 Walnut Street, Philadelphia 3 • 96 A Huntington Avenue, Boston 16 • and other principal cities.

CHEMICALS

(Continued from page 52)

- 2 **Neoprene Adhesive.** Industrial adhesive known as Neoprene Adhesive F-1 announced by Carboline Co. No accelerators, catalysts or two-part mixing required. Spreads readily, easily applied by spatula, brush, or spray. Easily bonded to sponge rubber & rubber strip to metal. Peel strength of 40 lb./sq.in. between two sheets of neoprene developed in 7 to 10 days.
- 3 **Polyvinyl Chloride Resin.** For use in calendaring & extrusion operations improved formulations of polyvinyl chloride resin from Dow Chemical Co. Designated Dow PVC-111-1 for calendaring; PVC-111-4 for dry blend extrusion. Good heat stability & low gel count of PVC-111-1 makes it desirable for high speed film & sheeting production. Applications for PVC-111-4 are wire covering, tubing & gaskets.
- 4 **Vacuum Grease.** Lockrey Co. announce a new principle in lubrication of vacuum apparatus. Mo-Silicone vacuum grease combines chemical inertness & excellent temperature-viscosity relationship of silicone liquids with good lubricating qualities of molybdenum disulfide. Technical bulletin available.
- 5 **Ammonia.** Technical aspects of handling, physical properties & allied subjects on ammonia discussed in 50-page technical booklet from Spencer Chemical Co. Many drawings & charts, details variety of uses, charts vapor pressure, specific volume & density.
- 6 **Molybdenum Disulfide Powder.** New grade of purest molybdenum disulfide powder, named Molykote-Micro-size commercially available from Alpha Corp. Major significance is reduction of particle size. Easy entry between surfaces to be lubricated when dispersed in liquids or greases. Said to have better covering ability than material of large particle size.
- 7 **Body Flux.** From Vitro Mfg. Co. a new body flux called Vitromix for lowering temperature of ceramic bodies. Material is a special blend of fine ground minerals, frits & chemicals. Used in larger amounts it permits small ceramic products to be fired rapidly & continuously in conveyor belt furnaces or decorating kilns.
- 8 **Propargyl Alcohol.** New grade of propargyl alcohol, 40% aqueous solution now offered by General Aniline & Film Corp. in addition to 97% pure material. Available in drum lots from pilot plant production. For use in synthesis reactions which may be conducted in presence of water, such as oxidative coupling to form hexadienediol & hydration to form acetol.
- 9 **Cement.** Atlas Mineral Products Co. Vitrobond a hot-poured plasticized sulfur cement, is used in capping concrete test cylinders, forming hubs of discs. Properties exceed requirements of A.S.T.M. specifications. Ten minutes after pouring said to be essentially as strong as concrete cured 30 days.
- 10 **Corrosion-Resistant Mortars.** Delrac Corp. furane & polyester cements are subject of bulletin. Lists physical properties, details chemical resistance materials.

BULLETINS

- 15 **Sleeve-Packed Cocks.** Folder from Klinger Corporation of America on a sleeve-packed cock. Renewable packing sleeve can be retightened in use or quickly replaced; plug being parallel it cannot jam; unobstructed straight-

through full bore passage. Types for variety of uses. Cutaway view.

- 16 **Air Jet Filters.** Johnson March Corp. folder on reverse air jet filters with self-adjusting blow rings. Said to give high filtration efficiency rates; automatic continuous operation. Schematic operating design shown; comparative illustrations of filter.
- 17 **Annual Diary.** Denver Equipment Co. annual diary. Provides efficient device for keeping permanent records of expenses, investments, taxes, important dates, other desired information.
- 18 **Integrator.** An electrically operated integrator from Rockwell Mfg. Co. mechanically computes metered volume of gases, steam or liquids from orifice meter charts. Features a counter setback assembly operating from main calibration post enabling operator to run practically all ranges of charts at any base pressure.
- 19 **Filter Medium—Filter Bed Agitators.** (19) Anthrafilt hard coal filter medium from Palmer Filter Equipment Co. representing Anthracite Equipment Corp. Folder asks & answers many questions in regard to use. Lists types for which medium is useful. (20) Use & operation of the Palmer filter bed agitator considered in separate bulletin. Sections on specifications, data sheets, installation, illustrations of actual installations.
- 21 **Centrifugal Pumps.** Bulletin on centrifugal pumps for special use in chemical, food & other process industries, issued by Goulds Pumps, Inc. Said to provide dependable pumping of acids, alkaline liquors, slurries. Describes construction details, outlines specifications, charts interchangeability of parts. Shows performance curves of nine sizes in which pumps are manufactured.
- 22 **Jet Sizer.** New bulletin from Dorr Co. on the Dorrco jet sizer. Describes physical characteristics, control mechanism, theory, operation, advantages & applications. Also includes illustrations of typical units. For sizing & grading eight mesh & finer solids. Flexibility of pocket arrangement & elimination of expensive construction plate construction featured.
- 23 **Cooling Towers.** Catalog from Acme Industries, Inc. treats in detail subject of cooling towers & how they save money. Five models illustrated & described. Capacities 3 to 15 ton. Advantages of heavy-duty, all-metal galvanized construction detailed. Suited to industrial installations of air conditioning & refrigeration.
- 24 **Electric Equipment.** General Electric Co. bulletin covers equipment for power generation, distribution & conversion. Also details power utilization, instrumentation. Illustrated, details construction & other pertinent information.
- 25 **Threading Pipe & Tubing.** Helpful hints on hand threading stainless steel pipe & tubing available in bulletin from Babcock & Wilcox Co. Covers die stock, dies, speed, cutting oils & joint assemblies. For special use of pipe fitters.
- 26 **Process Equipment.** Pressure filters, ion exchangers, heat exchangers, centrifugal pumps, rubber lining & covering service described in catalog from Industrial Filter & Pump Mfg. Co. Details construction, applications, gives cutaway views plus other illustrations.
- 27 **pH Instrumentation.** Complete instrumentation for pH measurement & automatic control is subject of bulletin from Bristol Co. For use in petroleum, pulp & paper, pharmaceutical, textile, other industries. Also shows accessories.

- 28 **Pressure Recorders.** Elements for measuring pressure said to have greater operating power and improved accuracy described in bulletin from Foxboro Co. Application chart shows choice of element materials available. Case & linkage features, charts, process ranges, accessories.
- 29 **Pump Materials.** Recently tested for comparative corrosion resistance Carpenter Steel Co. type 316 & stainless No. 20 exhibited useful resistance to attack of sulphuric acid. Combination of No. 20 and Teflon said to make small pump suitable for variety of chemical & nuclear engineering applications.
- 30 **Glass-Lined Tank.** Folder on Utilitank glassed inside & out for storage of neutral products where non-contamination, easy cleaning & non-adhesion are paramount. Pfaudler Co. List of products suited for ideal storage plus specifications & dimensions.
- 31 **Process Equipment.** Colonial Iron Works Co. illustrated brochure describes line of agitated kettles, exchangers, absorbers, plus information on plate fabrication. Available in a variety of alloys, several types of stainless & chrome steels.
- 32 **Dial Timer.** Binder insert from Automatic Temperature Control Co., Inc., on a repeat cycle dial timer. Controls two independently adjusted load circuits. Reversible motor principle an exclusive feature combines simplicity with accuracy & dependability. For use in lubricating systems, valves & dampers, solenoid valves, pumps, vats, sprays.
- 33 **Swivel Fittings.** Emsco Mfg. Co. ball bearing swivel fittings in size range 3/8 to 1 in. & working pressures of 6,000 lb./sq. in. at 225°F to 1,250 lb./sq. in. at 750°F described in illustrated folder. Sectional drawings. Various packing for steam, hot water, oil, chemicals, shown.
- 34 **Heat Exchanger & Condenser Tubes.** Made of Electrune carbon steel heat exchanger & condenser tubes from Republic Steel Corp. Meets A.S.T.M. specification A-214 applicable to tubing up to 2 in. O.D. Others in sizes 3/8 to 5 in. O.D. Bulletin shows diagram, gives test requirements, other data.
- 35 **Seal-less Centrifugal Pump.** Chempump Corp. centrifugal pump guaranteed not to leak. Unit operates without seals or stuffing box. Standard Chempumps available in cast iron, stainless steel & Monel construction, other materials. Handles fluids to 450°F temperature, pressures to 150 lb./sq. in. Simple modifications permit pumping at 600°F & pressures to 5,000 lb./sq. in.
- 36 **Control Valve.** Called Flash-Flo an exclusive plug design from Hammel-Dahl Co. with solid V-port, also step cone, spline & Holo valves. Illustrated bulletin includes cutaway view, details construction & other features.
- 37 **Centrifugal Pumps & Alloys.** (37) Folder from Ampco
- 38 **Metal, Inc.** describes centrifugal pumps. All bronze construction & resistant to corrosion, erosion, cavitation-pitting, deformation & wear. Other features include efficiencies to 85%, easy access to pumping parts. (38) Ampco aluminum bronzes of high strength, easy workability, & wear resistant, treated in binder insert bulletin. Physical properties, types, sizes, all pertinent information.
- 39 **Pipe Insulation.** MMM, Inc. Vapo Wall is a styrofoam pipe insulation. Material is a multi-cellular plastic foam produced by expanding polystyrene 40 times. Completely moisture-proof, lightweight, has high compressive strength, vermin- & fire-resistant. Available for use on all standard sizes of pipe, vessel & fitting covers plus special sizes. Leaflet gives recommended thicknesses, tells how to apply.
- 40 **Tank Heaters.** Brown Fintube Co. bulletin describes the TF-18 tank heater that mounts vertically and prevents sediment from settling on heating surface. Bottom of tank remains clean & uncluttered. Said to provide easy installation. Is economic in its heating as opposed to tank coils.
- 41 **Cathode Protection.** The whys and hows of cathode protection are set forth in booklet from National Carbon Co. a division of Union Carbide & Carbon Corp. A complete reference work on mitigation of corrosion of underground & submerged metal structures by application of an impressed cathodic protection system using graphite anodes.
- 42 **Computer Components.** Mechanical, electrical & magnetic computer components from Librascope, Inc. Folder carries photographs of each item in line with complete specifications & other operational information.
- 43 **Power Equipment.** Regulated power equipment manufactured by Sorensen & Co., Inc. is subject of extensive catalog. Covers electronic a.c. voltage regulators, regulated d.c. sources & B-supplies, frequency changers, inverters. Gives diagrams, physical & electrical characteristics, applications.
- 44 **Control Valve.** Ultravalve designed & engineered by Hammel-Dahl Co. said to solve many new application problems presented by modern process control. Dangerous flowing media handled with maximum safety. Self-lubricating, easily disassembled reducing maintenance problems & hazards to workers. Structural features, functional advantages, cutaway view other illustrations in folder.
- 45 **Industrial Conditioners.** Ovens, dryers, conditioners for industrial processing covered in illustrated bulletin from Lydon Bros., Inc. Included are electric conveyor ovens, mold ovens for investment castings, driers for chemicals, many others in various Fahrenheit degree specifications, Teflon ovens, cabinet ovens with pent house air heaters.
- 46 **Combustion & Heat Transfer Equipment.** Thermal Research & Engineering Corp. literature packet contains folders on each product in line. Specifications, construction, cutaway views & diagrams, detailed information on each.
- 47 **Cooling Towers.** "Cooling Water for Industry" is the title of a 36-page publication from Fluor Corp. Ltd. Said to be one of the most detailed explanations ever written on construction & applications of cooling towers. Describes Fluor induced-draft tower construction. Well illustrated, shows detail of structural & mechanical equipment.
- 48 **Pressure Control System.** Bulletin from CDC Control Services, Inc. describes in detail the solution of a difficult pressure control problem related to a blowdown tunnel. Typifies manner in which company specialists in automatic control can optimize systems in which combined transient & steady state response accuracies are stringent.
- 49 **Engineering & Construction Services.** From the Ralph M. Parsons Co. booklet describing services which they make available including engineering, construction, research, development, petroleum processing & fertilizer plant design & construction.
- 50 **Pressure Washer.** Removal of water soluble dirt & soil with minimum quantity of water using compressed air to break water into minute high velocity particles said

to be easily accomplished with use of Hydro-Air pressure washer from D & M Products, Inc. Harmless to finest finish it is applicable for cleansing processing equipment, trucks, etc.

- 51 **Drum Upending Bar.** Steel drums device permits safe, easy, one-man handling of heavy drums. Uses principle of leverage to multiply strength of operator minimizing strain & exertion. Lifting force of only 30% of weight of full drum required. Leaflet from Melooz, Inc.
- 52 **Centrifugal Pumps.** Precision built single- & multi-stage vertical centrifugal pumps from Pacific Pumps Inc. are subject of illustrated folder listing temperature, capacity, pressure, differential head information on each available type.
- 53 **Waste Recovery.** Bowen Corp. automatic recovery system said to provide economically feasible disposal of waste liquors from pulp & paper mills by using high thermal efficiencies obtained through compression distillation. Evaporation rates of 13 to 17 lb. of water evaporated per pound of net steam possible. Illustrated leaflet shows schematic diagram.
- 54 **General Catalog.** From Fischer & Porter Co. new 12-page general catalog with illustrations, descriptions & basic specifications for process instrumentation. Units for measurement & control of process variables include: flow meters, pressure & temperature instruments, air-operated control valves & many others.
- 55 **Processing Equipment.** Revised catalog from Patterson-Kelley Co., Inc. provides photos & specifications on many sizes & adaptations to their three basic types of blenders. Production sizes available on patented twin shell ribbon, & double cone models, & 1 pt. to 8 qt. laboratory sizes for twin shell.

EQUIPMENT

- 60 **Hydraulic Pump.** Complete description of the new Aldrich Pump Co. hydraulic pump contained in data sheet. Includes information on design, installation & operations. Meets demand for small volume capacity at low & high pressures. Single- or double-acting models. Develops to 30,000 lb./sq.in. at 90 lb./sq.in. air supply.
- 61 **Thermostat.** Fenwal, Inc. have developed a thermostat having heavy duty load carrying capacity & small differential. Recommended for applications where advantageous for thermostat to carry loads of 20 to 35 amps. without relay. Models for remote & direct installation. Bulb unit adjustable over range of 50 to 300F; remote unit has two ranges — 50 to 250F & 150 to 550F.
- 62 **Pressure Tight Fittings.** Century Products Inc. complete line of self flaring pressure tight fittings currently available in 1/4 to 1/2 in. sizes. Variety of types & materials. Brass fittings for copper tubing. Also anodized aluminum, cadmium steel, Monel metal, stainless steel. Illustrated leaflet supplies other details.
- 63 **Hand Pyrometer.** An aluminum dial feature added as an extra to line of Claud S. Gordon Co. Xactemp hand pyrometers. Permits pyrometer reading in poor light without auxiliary lighting. Two pen-lite batteries in handle of instrument.
- 64 **Pipe Clamp Thermocouple.** Accurate reading of outside pipe temperatures now possible by use of Conax Corp. adjustable pipe clamp thermocouples. Used where im-

mersion thermocouples are undesirable and where temperature readings on alloy, plastic or glass pipes are not easily entered. Complete size range for pipe from 3/8 through 4 in. I.P.S.

- 65 **Flow Regulators.** For automatically controlling flow of water, valve from Bell & Gossett Co. Brass construction valve has many applications in plumbing & heating field. Applications include tankless heaters, condensers, hot water heaters, pumps. 1/2 & 3/4" pipe sizes for capacities 2 to 8 gal./min. Leaflet shows diagrams.
- 66 **Tank Light.** Developed to assist processing of flammable chemicals an explosion-proof pendant tank light from Crouse-Hinds Co. Equipped with a type R 75 watt, 120 v. spot lamp suspended over a tank porthole, new fixture illuminates surface of mixture inside tank. Machined from cast aluminum, joints of the 12-1/4 in. X 6-7/16 in. fixture are threaded & completely flame-tight. Separate lamp receptacle capable of absorbing severe shock without damage. Qualifies for use at Class I, groups C & D hazardous locations.
- 67 **Gas Detector.** From Tallor & Cooper, Inc. for hazardous gases in low concentrations, a supersensitive analyzer. Diagram as well as operational information; specification; description of models included. Upper portion of one model detachable for use as mercury-vapor detector. Also useful for quantitative measurement of ultra-violet absorbing materials.
- 68 **Spectrometer.** Atomcounter, direct reading spectrometer incorporates many new electronic, optical & mechanical design innovations. Built on unitized construction principle for ease in servicing & repair. Functional components mounted in steel L frame supported by outer frame insulated to minimize temperature change effects. Jarrell-Ash Co.
- 69 **Recording-Controller.** A thermo electronic recording-controller added to temperature measuring instruments from Thermo Electric Co., Inc. Records on circular 12 in. chart; has either two-position or pulse-proportional control action. Either may be used with two-position valves. Accurate to $\pm 1/4$ of 1% scale range. Full scale travel in 4 sec. 23 scale ranges from -320° to +200°F. Also 0° to 3,000°F.
- 70 **Safety Valve.** Protection against over-pressure & fuel-fed fires in gas installations said to be assured with use of Valco Inc. safety valve. May be mounted in any position even upside down. Positive shutoff eliminates leakage in line. Gas flow is under seat. Illustrated leaflet shows schematic drawings, etc.
- 71 **Diaphragm Valves.** Added to line of Hills-McCanna Co. are valve line valves with polyvinyl chloride plastic bodies. Design plus P.V.C. expands list of corrosive materials that can be successfully handled. Available are hand wheel or lever operated, sliding stem & air operated types. Size range 1/2 through 2 in. Screwed ends are standard.
- 72 **Coolant Systems.** Folder from Easy Industries introduces improved coolant system. Capacities of systems in line to 1/2 HP., 50 gal./min. & tanks through 39 gal. For duty with drill presses, tappers, grinders.
- 73 **Plastic Pelletizer.** Unique cutting machine said to produce 5,760,000 pellets/min. offered by Taylor-Stiles & Co. Cuts plastic material without breakage. Has thirty fly knives. Series 700 designed primarily for plastics extruded in rod form. Two sizes — throat width 5-3/4 & 10 in. Operate on either wet or dry stock. Automatic

(Continued on page 58)



Caustic Soda

for the Soap Industry

Caustic soda is one of the basic chemicals required for the manufacture of modern soaps.

Uniformly high quality GLC GRAPHITE ANODES are basic too—in helping the electrolytic industry meet the growing civilian and defense needs for chlorine and caustic soda.

ELECTRODE DIVISION

Great Lakes Carbon Corporation

Niagara Falls, N. Y.



Morganton, N. C.

Graphite Anodes, Electrodes, Molds and Specialties

Sales office: Niagara Falls, N. Y. **Other offices:** New York, N. Y., Oak Park, Ill., Pittsburgh, Pa.

Sales Agents: J. B. Hayes, Birmingham, Ala.; George O'Hara, Long Beach, Cal.; Great Northern Carbon & Chemical Co., Ltd., Montreal, Canada

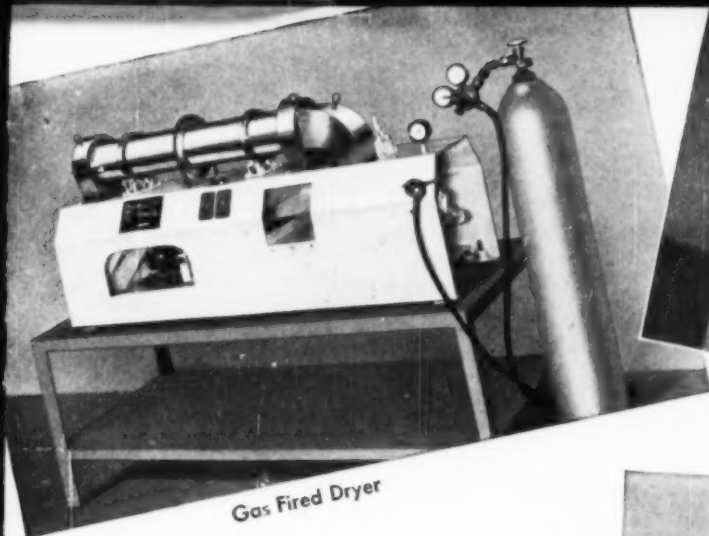
Overseas Carbon & Coke Company, Inc., Geneva, Switzerland; Great Eastern Carbon & Chemical Co., Inc., Chiyoda-Ku, Tokyo

EQUIPMENT

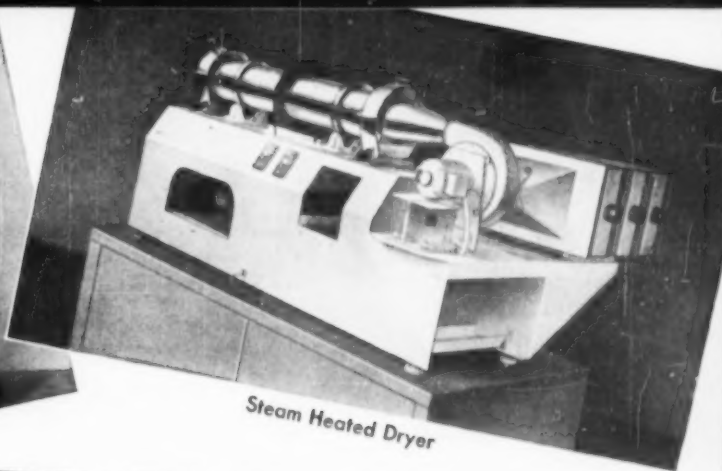
(Continued from page 56)

clutch for feeds & safety guards may be any desired shape & construction.

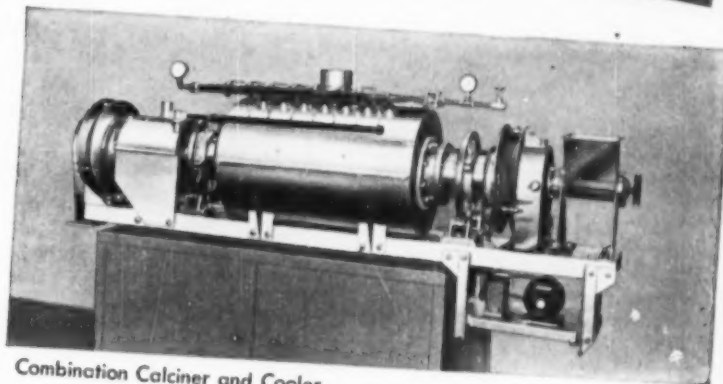
- 74 **Ultrasonic Cleaning Device.** McKenna Laboratories ultrasonics bulletin considers the use of ultrasonic vibrations in cleaning delicate, easily damaged parts such as vacuum tube grids. Also in initiating or accelerating chemical reactions; aging fermented & distilled beverages; sterilizing at low temperature; washing textiles in cleaning fluids; detecting internal flaws in rubber tires.
- 75 **Flow Meter.** Flow measurement element combining in-line installation simplicity & economy of differential orifice with linear measurement signal, wide range, & low viscosity sensitivity of variable area type meters. Sizes for installation in pipe lines from 1/2 to 12 in. to cover flow rates from 0.2 to 2,000 gal./min. liquid; 10 to 60,000 lb./hr. of steam; or 1 to 6,000 cu. ft./min. gas. Fabricated in large variety of materials including hard rubber & plastics. Devicengineering Co.
- 76 **Capacity Level Indicator.** Capable of providing continuous indication of level for many materials in storage or process, Belmont level indicator from Thermo Instruments Co. Utilizes a capacitive-type sensing-element probe without floating or moving parts. May be used with most non-adhesive chemicals, milk, oils, Freons, & all condensed gases. Operable over a temperature range of 500 to -425 F from high vacuum to 100,000 lb./sq. in.
- 77 **Tank Gauge.** Known as Magnalux tank gauge with automatic reading shows height of any liquid including liquefied gases stored under pressure. Fitted with leak-proof tank seal capable of withstanding any amount of pressure or vacuum. Bulletin contains schematic drawings, operational information, lists features. Liquidivision Gauge & Control Corp.
- 78 **Aluminized Asbestos.** Heat reflecting aluminum & fire resistant asbestos are combined to give extra protection against high temperatures & flames in asbestos clothing from Industrial Safety Specialties Co. Designed for workers in industry, truckmen, firemen. Fully described & illustrated in folder. Line includes hoods, gloves, coveralls, rescue suits & kits.
- 79 **Water Softeners.** Folder from American Water Softener Co. describes three-stage reactors for softening or clarification of surface water for process, industrial & municipal applications. Said to feature infinite variation of agitation, accelerated precipitation by sludge recirculation between secondary & primary zones, submerged orifices for eliminating uneven takeoff distribution. Diagrams, details of construction.
- 80 **Automatic Batching & Quantity Control Valves.** (80.)
- 81 From Rockwell Mfg. Co. Fluidometer system for automatic batching of light or heavy liquids developed by Hetherington and Berner, Inc. Consists of a Rockwell Rotocycle measuring element, motor-operated control register & solenoid valve. (81.) Quantity control valves said to eliminate severe hydraulic shock which accompanies rapid cutoff of large volume flows now available in sizes 2 to 6 in. For refinery & marketing operations of petroleum industry.
- 82 **Monel Demister.** Pamphlet from Otto H. York, Inc. reports two case histories on use of Monel wire mesh demister installed in compressor suction drum of de-asphalting unit. Said to reduce costs on propane compressors. Also gives information on installation of unit in compressor suction line of catalytic cracking unit.
- 83 **Pilot Plants.** Packaged pilot plants now available from Patterson-Kelley Co., Inc. Reaction-distillation plants range from 5 to 60 gal. capacities. Small reactors flexible & convenient for pilot work also available. All units are field tested.
- 84 **Zeolite Water Softeners.** Industrial zeolite water softeners are individually designed to meet particular size & capacity requirements for soft water in food & processing plants, power plants, railroad locomotives, textile plants & for potable soft water supply. Controls for manual or automatic operation. Industrial Filter & Pump Mfg. Co.
- 85 **Poly-V Drive.** Raybestos-Manhattan, Inc. offer new concept of belt power transmission described in brochure. Two-color line drawing explains fourteen specific advantages claimed for drive. Said to give twice contact area, 50% more horsepower, eliminates matching, many other features.
- 86 **Bin Level Indicator.** From Bin-Dicator Co. news of a built-in bull's eye signal light for use in installations requiring a signal. Readily seen by operation. Addition of light to standard model is minimum cost. Applicable to packaging hoppers, scale hoppers & small bins handling bulk materials.
- 87 **Process Pump.** Folder from Vanton Pump & Equipment Corp. details their Sani-Flex sanitary pump designed for the dairy, food, pharmaceutical, bottling, chemical industries. No stuffing boxes, shaft seals, check valves or gaskets. Self-priming, self-draining & non-agitating. Easily disassembled. Diagram shown.
- 88 **Automatic Immersion Heater.** Thermostatic control & safe, reliable Corox element combined in one-piece immersion heater available from Westinghouse Electric Corp. Control unit eliminates need for mounted & wired temperature regulating device. Power ratings 750 to 2,500 w. for 118 or 236 v. applications.
- 89 **Pressure Transmitter.** Swartwout Co. announces pressure transmitter without stagnant pressure lines. Designed for use with units of company's Autronic control system. Claims special advantages with polymers, asphalts, slurries, molten metals & viscous fluids which solidify when stagnant. Construction permits free movement of low displacement diaphragm.
- 90 **pH Indicator.** For continuous measurement of pH in manufacturing processes a panel-mounted indicator from Leeds & Northrup Co. Said to be moisture-proof, gives accurate readings after less than a minute warmup without use of desiccants. Unaffected by line voltage surges, electrical pickup & zero drift. Illustrated leaflet shows diagram.
- 91 **Variable Speed Drives.** Newly added to line of Cleveland Worm and Gear Co. the Cleveland Speed Variator available in 9 sizes from 1/2 to 10 h.p. at 1750 input rev./min. Operating efficiencies of 75 to 90% maintained over wide range operating conditions. Coaxial input and output shafts rotate in same direction, either clockwise or counter-clockwise. Illustrated folder gives additional data & diagram.



Gas Fired Dryer



Steam Heated Dryer



Combination Calciner and Cooler

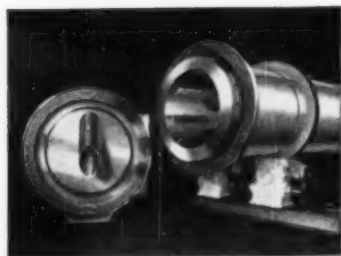
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Send us samples of your products. Tell us the conditions and let our technicians make the test runs, preferably with your representatives present. All the test units illustrated have been standardized and are available for purchase by concerns maintaining their own testing laboratories.

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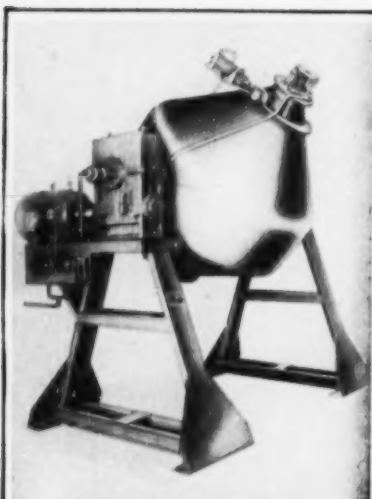
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Centrifugal Compressors

(Continued from page 39)

processes in the refinery) for the recovery of ethylene, ethane, propylene and propane. The ethane recovered in the original process is cracked again for the recovery of additional ethylene, while still more ethylene is recovered from the furnace effluent and the furnace recycle stream. Design capacity for this

are added to the compressed furnace effluent gas. The combined gases are finally compressed from 240 to 720 lb./sq.in.g.a.

Necessary refrigeration is provided by the two remaining compressors in this large installation. A closed refrigeration system using propane as the refrigerant operates at three different cooling levels, minus 10°F., 18°F., and 49°F. In this system the propane is recycled and condensed against water, while the ethane system is of the open type using ethane as the refrigerant and then rejecting it to the process.

In order to present a general picture of the size and type of equipment installed, a brief word picture of the machine building is in order. The five Worthington centrifugal compressors, all driven by Worthington turbines, are located side by side under the same roof, which is actually all there is to

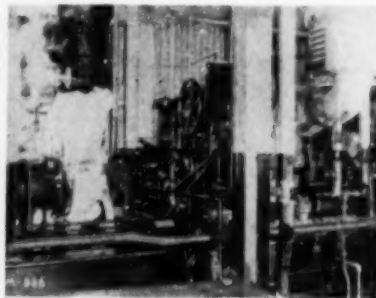
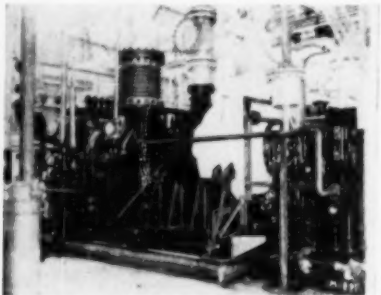


Fig. 4. 720 horsepower gas expander "C" provides part of the power to drive charge gas compressor "B".

Fig. 5. 6-stage centrifugal compressor "D" driven by a 5,000 Hp. steam turbine. This unit also takes a bleed-in stream from the desulfurization plant two miles distant.

Fig. 6. Ethane compressor "E". Note the bleed-in nozzle.



plant is 180,000,000 pounds of ethylene per year from the refinery gases and gases resulting from the cracking of the ethane. These figures are design values based on 330 operating days per year.

Three of the compressors handle five different charge streams in the process while the other two units are refrigeration compressors providing the refrigeration needed in the process.

Two light hydrocarbon gas streams are handled by the compressors. Furnace effluent is compressed from 15 lb./sq.in. ga. to 260 lb./sq.in.g.a. in "A" and "B" with the latter compressor driven by a turbine and expander. At the 260 lb./sq.in.g.a. pressure level, the desulfurized and carbon-dioxide-free refinery gases

the building. The entire ethylene plant is of the outdoor type, which has proven popular in the temperate climate of the southwest. In the ensuing description, all capacities, pressures, temperatures, and other operating data are design values.

The quantities noted in the accompanying table refer to initial suction and do not include additional gas bled in at intermediate pressures. Thus, in the case of the "F" units, initial suction is 93,400 lb./hr., then a bleed-in between the first and second stage impellers of 210,610 lb./hr. and further bleed-in between the second and third stage of 118,273 lb./hr. In the "E" unit, initial suction is rated at 27,930 lb./hr. with a bleed-in between the first and second stage impellers of 126,450 lb./hr. This illustrates the flexibility of a centrifugal compressor which can bleed in gases at varied pressures and raise them all to a single discharge pressure. Impellers and volutes for a given casing size can be arranged so that the second stage handles double the volume of the first stage and the third stage triple the volume. The twin volute design used in this plant

(Continued on page 64)

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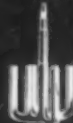
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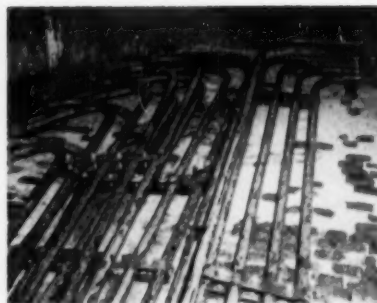


process equipment applications engineering

A stainless steel alloy exhibiting unusual resistance to sulfate attack and which can be fabricated or repaired by welding in the field without the need for final annealing has been operational tested in boiling alum for five years with little perceptible corrosion. The alloy known as Carpenter Stainless No. 20-Cb is being used for heating coils in four alum evaporators operated by the American Cyanamid's Warner Works in Linden, N. J. Use of the alloy has completely eliminated down-time for maintenance and has assured uniform product quality by contributing no contamination to the alum solution.

The evaporators handle an alum solution with a concentration range of $8\frac{1}{2}\%$ to 17%, and a temperature range of 239° F. to 245° F. The pH of the solution is approximately 2.5.

Prior to the use of stainless 20-Cb, the company made its heating coils from lead covered and plain red brass. Continual repairs were necessary with resulting interruptions in production.



When the coils were brass, steam would frequently leak into the alum solution and make it impossible to attain the desired product quality from the evaporators.

Production officials in charge of the installation estimate that the stainless coils will have a useful service life of approximately 25 years. The coils which have been in operation since 1949 are still in service with no trace of pitting and little evidence of general corrosion, the estimated corrosion rate being .001 in./yr.

Stainless No. 20-Cb is primarily a sulfuric acid resisting steel. Its unusual resistance is obtained with a high nickel content of approximately 29%, fortified with high chromium (20%), and Molyb-

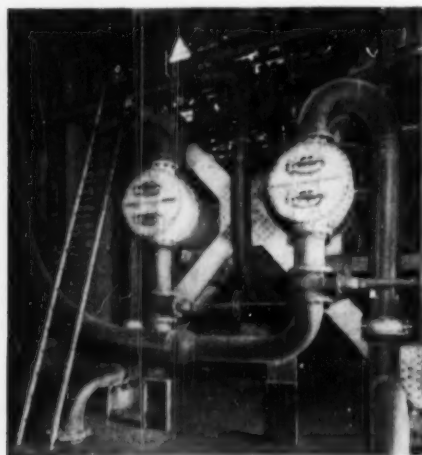
denum (2%) for building a more pitting-resistant film. Addition of Columbium to the alloy, about eight times the minimum Carbon content of .07%, minimizes the precipitation of carbides during welding and allows fabrication by welding without final annealing.

It can be used with up to 78% concentration solutions at temperatures of about 125 F. It is highly resistant to all other concentrations up to 176° F. and up to 10% at boiling temperatures.

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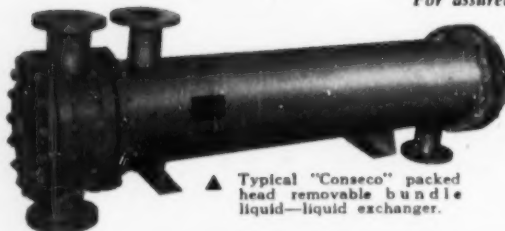
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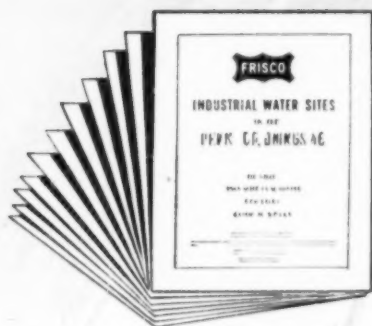
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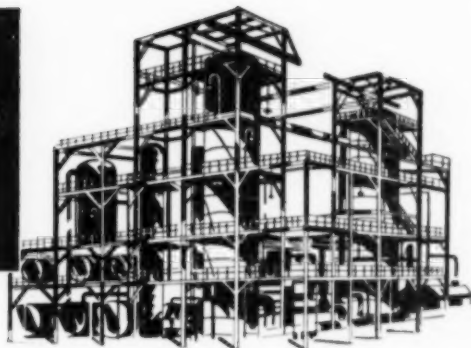
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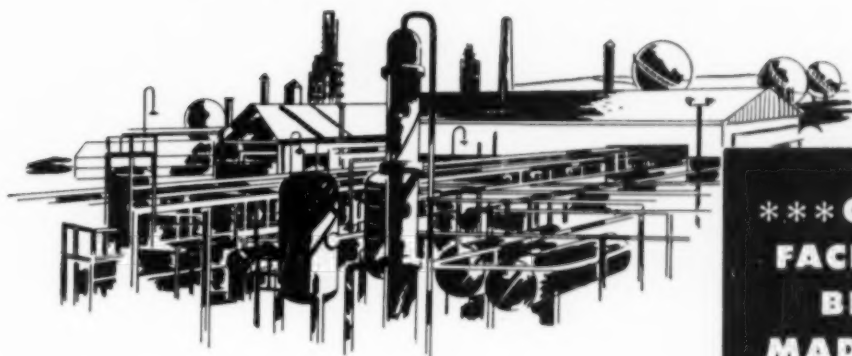
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The Hills-McCanna Uscolite bodied valve is available in standard sizes from 1/2" through 2". It is suitable for pressures to 150 psi and for temperatures to 170° F. (at some sacrifice of pressure rating in larger sizes).

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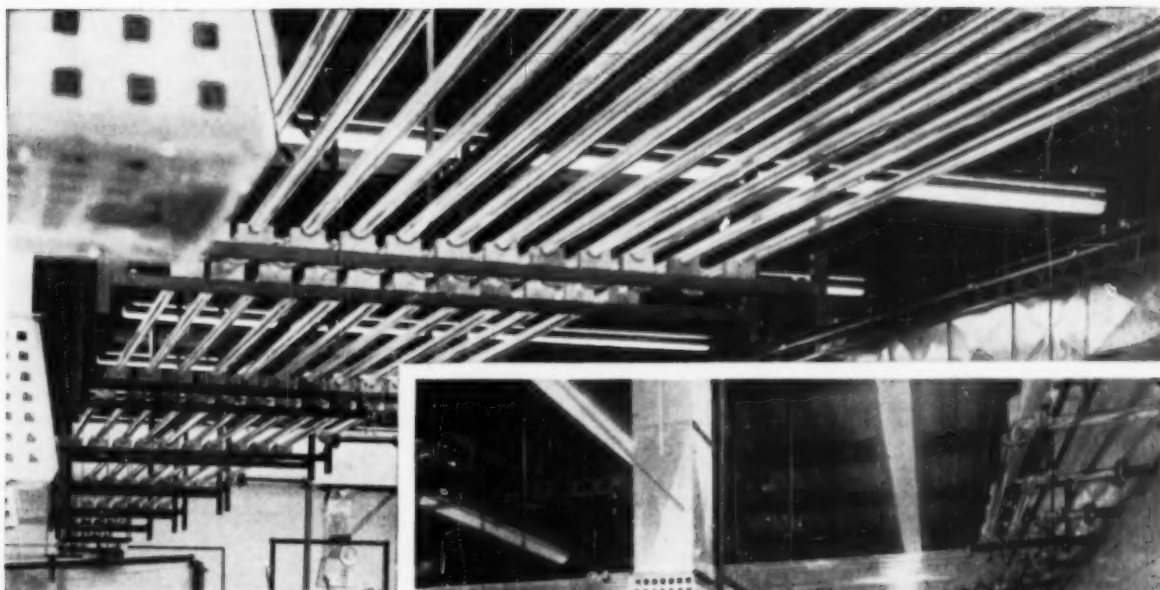
PHILLIPS BUYS CURRY CHEMICAL

The acquisition of Curry Chemical Co. and 14 affiliated companies by Phillips Petroleum Co. adds additional agricultural ammonia and mixed fertilizers to Phillips fertilizer producing facilities. No changes are contemplated in the operations of the companies and they will continue to operate with offices at Scottsbluff, Nebr. W. A. Curry, Jr., who heads the company will detach himself from the operation.

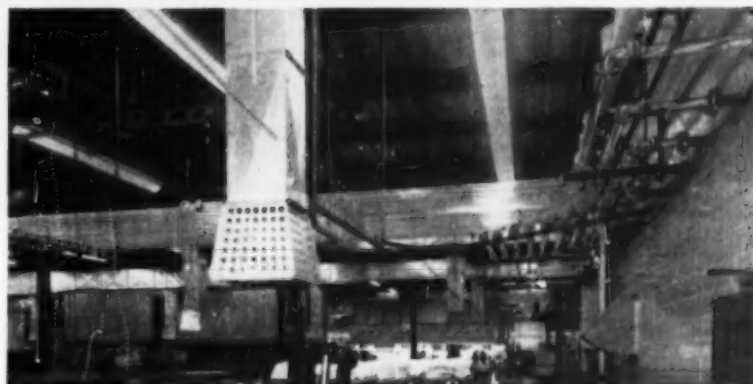
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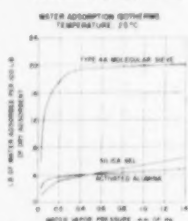
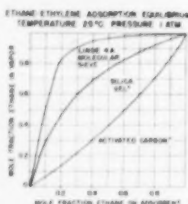
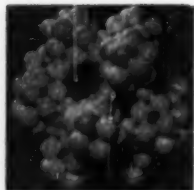
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due to a unique property of selective adsorption allow gaseous and liquid separations impossible with other available adsorbents and extremely difficult, if at all possible, with other separation techniques. These new materials which separate on a totally new basis — molecular size — are now being economically manufactured by the Linde Air Products Co., a division of Union Carbide and Carbon Corp. Their presence on the market gives impetus to the growing applications of adsorption techniques in separating mix-



tures into their pure compounds. Adsorption, which could easily rank along with distillation and crystallization as an operation for separations, has up to now been held back by limitations on the part of available adsorbents.

These adsorbent materials are sodium aluminum silicate or calcium aluminum silicate crystals in which the water of hydration has been driven off. Con-

trary to the reaction of dehydration in most materials, in these the crystalline structure is retained leaving empty cavities in which the water was located. The diameter of pores which enter into these cavities vary in diameter dependent upon whether the crystal is a sodium or calcium derivative. The empty cavities in the activated crystals have a tendency to recapture the water molecules that have been driven off in the manufacturing procedure. If no water is present they strongly attract anything that will fit into the cavity. Only those molecules that can pass through the pores of the crystal can get into the cavities and be held. This sieving action makes it possible for these molecular sieves to separate molecules smaller than the size of the pores from those that are larger. One type of crystal has a 4 Angstrom pore opening and the other has a 5 Angstrom pore opening.

Although this molecular sieve action of these adsorbents is their most unusual property, the usefulness of molecular sieves depends upon their adaptability to a wide range of conditions in a wide range of processes. Molecular sieves will adsorb water in higher capacities and at lower adsorbate concentrations than silica gel and activated alumina. This allows dehumidification of gases to a higher degree. Molecular sieves can adsorb materials at a much higher temperature than existing adsorbents. In this they have an advantage in that they can be used without removing the heat of adsorption or without expensive cooling thus saving money on cooling coils. They have a strong affinity of polar molecules and can separate polar molecules from non polar molecules even though the molecular sizes may be the

molecular sieves

new selective adsorbent announced by Linde

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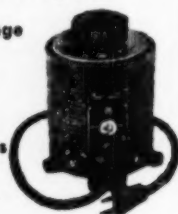
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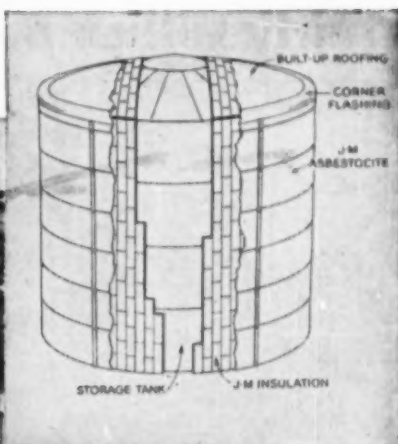


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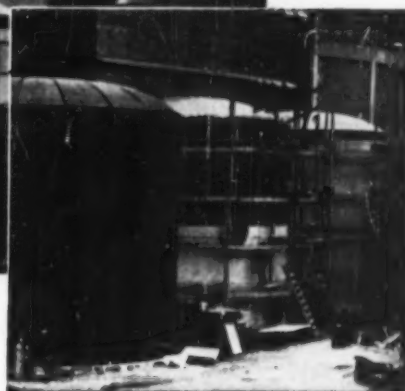
(Continued on page 70)

Cutaway drawing shows how J-M Weather-Protected Insulation is applied to tanks such as those at the S. D. Warren Company paper mill. Standard methods for mechanical securing of the insulation are used. Asbestocite sheets are then applied over the insulation, in accordance with the simplified Johns-Manville specification.



▲ (Above) Completed job of J-M Weather-Protected Insulation on black liquor tanks of the S. D. Warren Company.

(Right) Skilled applicators of an outstanding J-M Insulation Contractor, P. S. Thorsen Co. of South Boston, Mass., applying Asbestocite sheets over Zerolite insulation.



S. D. Warren Company saves fuel, reduces maintenance on outdoor tanks with J-M Weather-Protected Insulation

On black liquor tanks of the S. D. Warren Company paper mill at Cumberland Mills, Maine, Johns-Manville Weather-Protected Insulation pays a "double dividend":

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It helps provide close temperature control. The temperature of black liquor in these tanks must be maintained so that it will flow freely and not clog up pumping apparatus. J-M Weather-Protected Insulation helps do the job dependably and economically.

Whatever the operating temperature of outdoor tanks and vessels, Johns-Manville offers the right insulation for application under the Asbestocite weather protection. For example, J-M 85% Magnesia Insulation is also widely used for this service because of its proved performance for temperatures to 600 F.

To be sure that the insulation and its weather protection is properly applied to pay the greatest return on your investment, J-M offers the services of experienced J-M Insulation Engineers and J-M Insulation Contractors. These men stand ready to give you an insulation job that will more than pay off your initial investment through maximum fuel savings.

For further information about J-M Weather-Protected Insulation, write to Johns-Manville, Box 60, New York 16, New York. In Canada, 199 Bay Street, Toronto 1, Ontario.

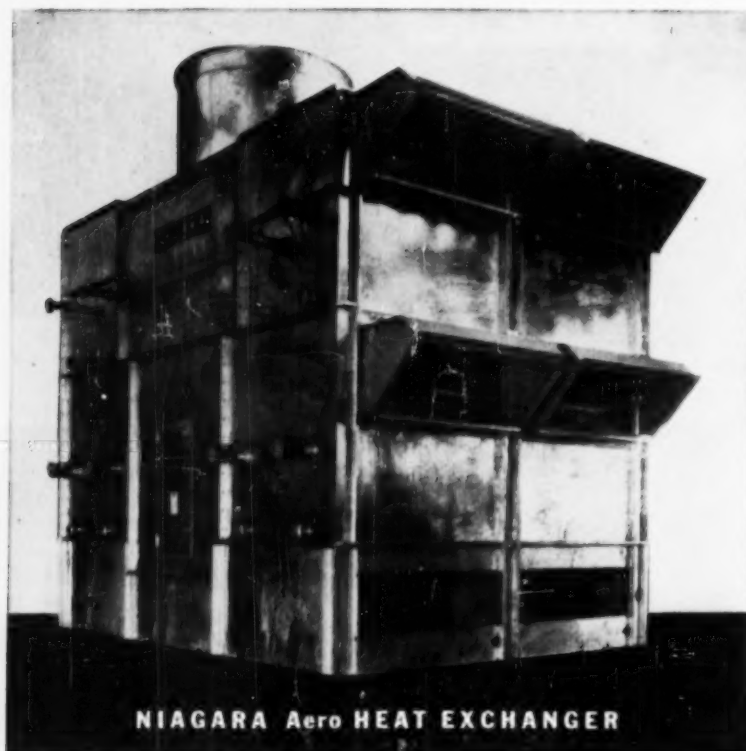
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MOLECULAR SIEVES

(Continued from page 68)

same. They show a marked affinity for unsaturated compounds and can separate saturated and unsaturated molecules of the same size. Liquid water does not damage these materials. The pellets remain whole and strong when wet. This allows their use in removing water from a gas stream without changing stream composition. They can be used to purify gas streams that are poisoning catalysts or causing corrosion; or can be used to recover gases from waste gas streams.

Of importance to continuous operation is their ability to be deactivated. The time required for reactivation is necessary to determine the number of adsorption units which must be made available to assure a continuous alternate operation. It is a simple matter to drive off adsorbed material from molecular sieves by heating and purging. Therefore the same batch of material can be used over and over in a cyclic process. This allows reclamation of adsorbed material for recycling or other use. Although molecular sieves can be heated as high as 1100° F. without causing serious damage, a recommended temperature for water desorption is between 300 to 600° F. With regard to the time required for reactivation, it is easily possible to reactivate an adsorber in a shorter time than was required for the adsorption cycle thus allowing a balanced and continuous operation with only two adsorbers.

Separations that are difficult to obtain by other methods can now be carried out by utilizing the small pore diameter and the selectivity of molecular sieves. Straight chain aliphatic compounds can be separated from cyclic and branched chain compounds. The type 5A molecular sieve quantitatively separates such mixtures because the straight chain compounds are small enough to enter the pores into the cavities in the crystal whereas the cyclic and branched chain molecules are not. Present examples of such separations that are being carried on are the separation of *n*-tetradecane from benzene, separation of *n*-heptane and methylcyclohexane, and purification of isopentane.

The opportunities for usage of these adsorbent materials are quite numerous. A recent survey of potential users of these compounds for use both as a substitution for available adsorbents and as a useful material for new separation processes found a request for more information and sample tests from about 85% of those contacted. The material comes in powder and pellet form in various sizes for direct substitution in present equipment.

Professional Progress Award

(Continued from page 40)

A.A.A.S., A.C.S., A.I.C., and holds membership in many others. He is a registered professional engineer in the Commonwealth of Pennsylvania and is also a member of the Cosmos Club, The Chemists' Club (New York), Marshall Chess Club (New York), American Go Association. His fraternities include Sigma Xi, Sigma Chi, Sigma Pi Sigma, and Phi Lambda Upsilon.

William H. Walker Award

(Continued from page 40)

and fine chemicals, rubber, petroleum refining, and equipment construction. He has been associated with Ionics Corp. as president, a member of the Board of Dewey and Almy Chemical Co., and a member of Board of Advisors to the American Research and Development Corp.

In 1944 Dr. Gilliland was the recipient of the Bakeland Medal and Award, for achievement in Chemistry, and was honored by the A.I.Ch.E. in 1950 as the recipient of the Professional Progress Award.

He holds membership in A.I.Ch.E., A.C.S., National Academy of Sciences, American Academy of Arts and Sciences, S.C.I., and Sigma Xi.

DUPONT BUILDS NEOPRENE PLANT

The expanding market for neoprene rubber has resulted in a decision by Du Pont to go ahead with construction of new plant in Montague, Mich., and the expansion of their existing neoprene production facilities in Louisville, Ky. The Montague plant will be supplied by pipeline with raw materials from both the Hooker Electrochemical Co. plant in Montague and a new Union Carbon and Carbide plant to be constructed in the same area.

Du Pont will break ground next spring for the new plant which will be built on a 1,000-acre site adjacent to the Hooker Electrochemical, who will transport hydrogen chloride by pipeline. Facilities will consist of a combination office building and laboratory, three manufacturing buildings, and a number of smaller structures. It is scheduled for completion in the latter part of 1956 and is expected to employ about 250 persons. Design and construction will be conducted by Du Pont's own engineering department. About 500 will be employed at the peak of construction.

Union Carbon and Carbide will supply the acetylene by pipeline from a new plant to be built in the same area.

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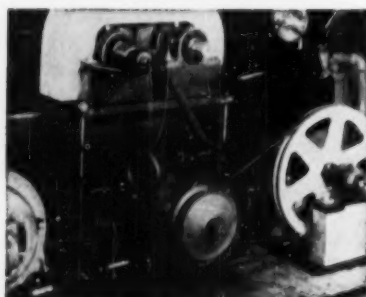
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ENGINEERS NEED MORE SCIENCE, SAYS A.S.E.E.

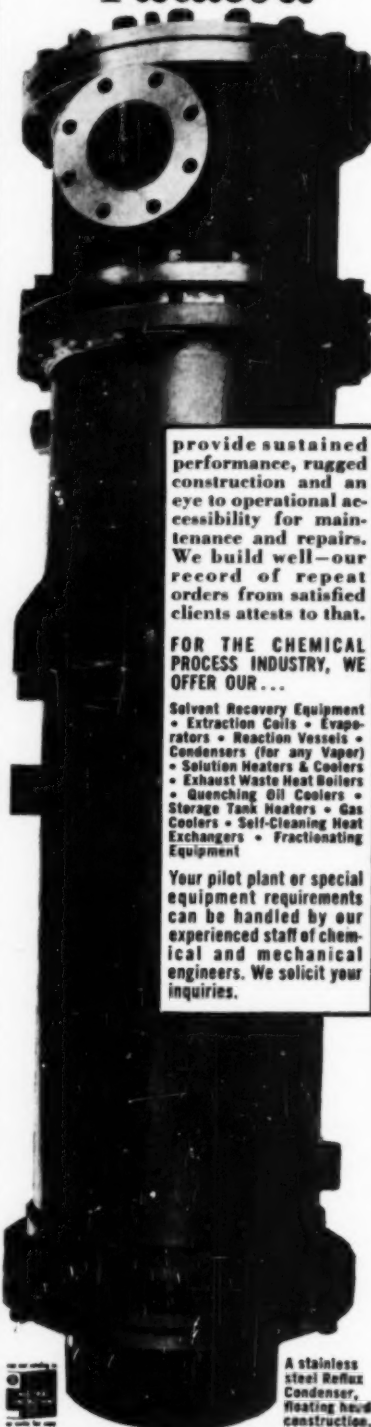
The desirability of providing a strong scientific background for engineers even at the expense of courses in applied engineering, or engineering art, has been stressed in the recently issued interim report of the Committee on Evaluation of Engineering Education of the American Society for Engineering Education. It is suggested on the basis of information received from educators and industrialists that more than half the total hours of undergraduate credit should be used for mathematics and basic science and for engineering science. The new report is a development of the preliminary report reviewed in the February issue of C.E.P., page 42A.

The engineering colleges reviewing the preliminary report seemed strongly in favor of curricula approaching the professional-scientific one outlined in that report as emphasizing mathematics and physical science; the nine engineering sciences; and a sequence of courses in engineering analysis, design, or engineering systems. Representatives of seven of the largest employers of engineers, who were invited to meet with the committee, agreed, and "emphasized that their sales, manufacturing, and operation or maintenance engineers needed strong scientific backgrounds just as much as the research and development engineers and designers." These companies employ less than 25% of their engineers in research, development, and design.

This general agreement suggested the desirability of a common stem of about 100 semester hours, including about 20 of humanistic-social subjects, for all engineering students, with about 20 hours of departmental courses in analysis, design, and engineering systems and about 18 hours of electives. The committee stresses that "it intends this skeleton curriculum to be considered as suggestive rather than restrictive. The great need of engineering education at this time is for experimentation with, rather than standardization of, curricula."

Besides the "evolution of a common stem," the interim report considered the selection and development of an engineering faculty, with emphasis on the securing of superior, well-rounded instructors; the treatment of gifted students; the place of high school preparation; graduate work, which will be dealt with more fully in another report; and the place of the professional engineer in society.

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TITANIUM PRODUCTION HITS NEW HIGH

Full capacity production of 10 tons per day of high quality titanium sponge has finally been achieved by the Titanium Metals Corporation of America at its Henderson, Nevada, plant. The new annual production rate at Henderson exceeds the combined 1952 and 1953 total output of titanium metal by all companies in the country. T.C.A., owned jointly by National Lead Co. and Allegheny Ludlum Steel Corp., is the only producer or potential producer involved in complete recycling of all by-products, recapturing much of the magnesium and chlorine consumed in the production of the titanium sponge. This metal having an astounding combination of high strength, low weight, corrosion resistance, and abundant ores has spurred heavy military research into its basic metallurgy. Technical information about titanium can be obtained in a 26-page listing of government titanium research reports available from the department of commerce.

LINDE INCREASING SILICONE CAPACITY

The tremendous industrial demand for silicones has prompted the construction of a \$14,000,000 plant at Long Reach, W. Va., by Linde Air Products Co., a division of Union Carbide and Carbon Corp. The contract for the equipment erection and process piping has been awarded to Kaighin & Hughes, Toledo, Ohio. Baker and Coombs, Morgantown, W. Va., will construct the process buildings. Linde is marketing such silicone products as electrical insulating varnishes and resins, mold release agents, and silicone rubber gum stock.

CYANAMID SHIPS ON NEW PAPER PALLET

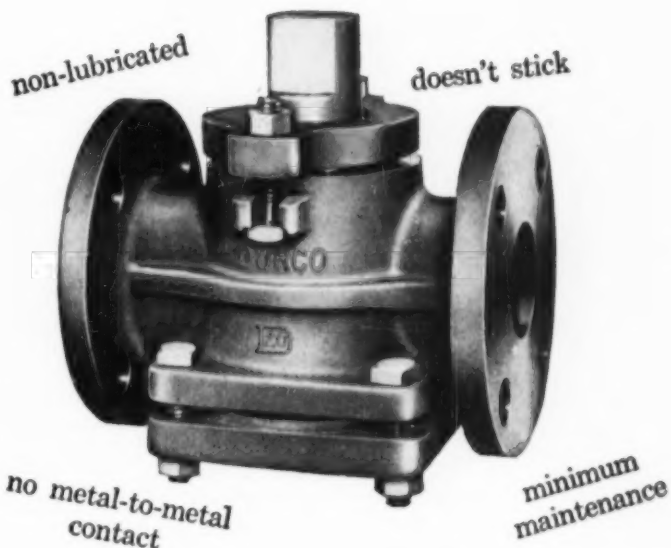
A new paper pallet that cuts unloading time to one fifth of that required by ordinary methods has been developed by American Cyanamid Co. for shipment of bagged and some packaged commodities.

The Accopak pallet is made of paper treated with Cyanamid's Melostrength resin. Tubes are inserted on either side of the pallet to receive the handling fork, also developed at Cyanamid. Stacking palletized shipments in warehouses is possible without removal of the pallets, which can also be easily stored and assembled. The bayonet-type fork fits any fork-lift truck.

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New York.

New York honors Tyler

A tribute to Steve Tyler, retiring executive-secretary of the Institute, was made by the New York Section at their November 17 meeting. Steve was presented a sterling silver cigarette box "for his untiring contributions to the Institute over the last seventeen

years and for the promotion of chemical engineering as a profession." F. B. White presented Steve with the gift on which was inscribed "To Stephen L. Tyler with affectionate regard from the New York Section of the American Institute of Chemical Engineers, Novem-



ber 17, 1954." Presentation of cards carrying life membership privileges in the New York Section was made to all past Local Section Chairmen. Procedures for evaluating technical personnel were presented as a technical part of the meeting. Mr. Kinckiner stressed the importance of graphically describing their qualifications and progress so that they know that there is some logical system by which their accomplishments are evaluated and by which they will receive advancements. He described several systems that are used by industrial psychologists and in particular those used at Du Pont. —S. ADLER

Southern California. The announcement of the 1955 officers and a talk on the Brea Chemicals Plant in Brea, Calif., were the highlights of the Oct. 19 meeting of the Southern California Section in Los Angeles.

The demand for ammonia is growing so fast, M. J. Laituri, senior project engineer at Brea Chemicals said, that already they are making expansion plans on their new plant for next year. The plant which went on stream in May of this year was designed to produce 250 tons of ammonia and 70 tons of dry ice per day. Of interest is the fact that the plant is so built that the ammonia is made in two parallel streams.

The 1955 officers announced at the meeting were as follows: *Chairman*, S. G. Sevougian; *Vice Chairman*, R. E. Vivian; *Treasurer*, P. M. Heummer; *Secretary*, Blaine Kuist; *Senior Member Exec. Committee*, J. J. Jacobs, Jr.; *Junior Member Exec. Committee*, H. W. Kellar; *Delegate to L.A. Engineering Counsel*, J. W. Jensen. —F. W. SAWYER

Rochester. Servomechanisms applied to process control problems was the subject of a talk presented to an Oct. 13 meeting of the Rochester Section by C. W. Bowden, chemical industries sales manager, Minneapolis-Honeywell, Brown Instrument Division.

Mr. Bowden in his talk on servomechanisms—self regulating automatic control systems—emphasized the needs of systems control engineers for more study in engineering fundamentals, mathematics, and electronics to keep up with the growing needs of industry for automatic control systems. —R. R. KRAYBILL

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Most economical of the granular drying agents, Florite has a longer service life, gives a low dew point depression, and aggressively resists "poisoning effects" which permanently destroy adsorption qualities.

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Knoxville-Oak Ridge. Reduced instrumentation costs and the elimination of manual logging by supervisory personnel were two of the points covered by R. K. Stern, director of data reduction and automatic division of the Fischer and Porter Co., in his talk before a joint meeting of the ISA and the Knoxville-Oak Ridge Section. The new automatic logging equipment has been designed for use at the operating level in chemical process industries. The section officers for 1955 were announced at the November 3 meeting.

Mr. Stern pointed out that while the initial justification of the automatic logger has been on the basis of reduced investment and space requirements, the elimination of manual logging by supervisory personnel and increased accuracy of logged data during upset conditions, is now found in the ability of the equipment to increase process efficiency through automation.

The equipment process measurements are received as pneumatic and electrical signals and converted to digital form for recording both as a typewritten log and on a punched tape. Variables may be integrated continuously and logged as accumulated information.

The local section officers for 1955 are *Chairman*, H. F. Johnson; *Chairman-Elect*, R. N. Lyon; *Secretary*, E. F. Martin, Jr.; *Treasurer*, W. S. Lenihan, Jr.; *Directors*, J. Shacter, F. L. Culler, Jr., A. C. Jealous.

—R. P. MILFORD

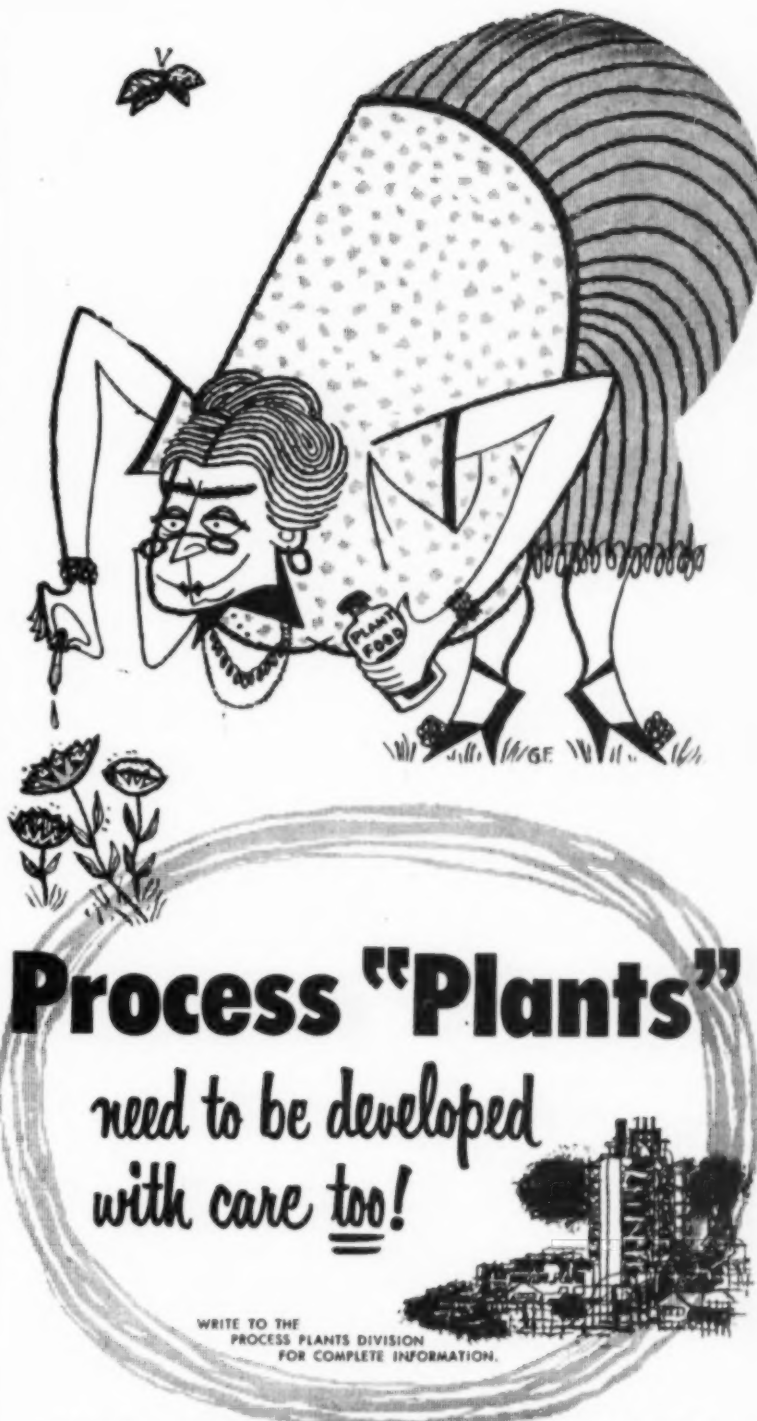
Savannah River. The method of artificially producing heavy elements was discussed by I. Perlman, University of California, at the November 9 meeting of the Savannah River Chemical Engineers' Club in Aiken, S. C. About 80 members and 75 guests heard Mr. Perlman talk on the production, the separation, and identification techniques used in the process.

The construction challenge of erecting the \$1.5 billion dollar A.E.C. Savannah River installation was told to the October meeting of the club in North Augusta, S. C., by A. D. Day, assistant field project manager at the plant.

—R. W. HINTERLEITER

Coastal Georgia. Election of officers for 1955 was the main business of the November 12 meeting of the Coastal Georgia Section held in Savannah. Officers are A. H. Riley, Jr., *Chairman*; L. Hawk, *Vice-Chairman*; J. K. Read, *Secretary*; and T. S. Burns, *Treasurer*.

—J. C. POWERS



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Resins . . . Soaps and Detergents . . . Fermentation Products . . . Pharma-
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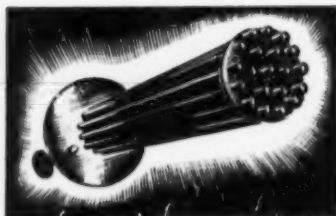
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News of the Field

FROM LOCAL SECTIONS

Midland. The design of fluid mixing equipment was analyzed before the Midland Section at their Oct. 9 meeting held in Midland, Michigan. J. Y. Oldshue, Mixing Equipment Co., Rochester, New York, in his talk, "Fluid Mixing—A Glimpse Into the Future," said that much headway is being made in correlating design variables. Mr. Oldshue is the chairman of the agitators testing committee of the Institute.

Mr. Oldshue pointed out that process design, impeller power characteristics, and mechanical design are the factors affecting mixer design. Of these power to the impeller is the most important variable; impeller input being a direct function of the product of impeller flow and impeller head. He said that all of the mixing is done in the fluid area generated by the impeller.

Movies of various experimental flow patterns were shown and it was illustrated how these patterns are aiding in the design of impellers. The ultimate aim of design is to have process flow and impeller head determine impeller size so that there can be general correlation among many different process systems.

The Midland section is planning to sponsor an educational television program. Its theme will be everyday chemical engineering and chemistry. The program will be on Sunday afternoon and will start in January and run through June on a once-a-month basis.

—G. KOCH

Central Ohio. Mechanical aids for literature searching were discussed by J. W. Perry of Battelle Memorial Institute before the Oct. 20 meeting of the Central Ohio Section held at Ohio State University. Mr. Perry stated the main problem to be the identification from a vast amount of accumulated material of the reports, papers or records that are to be of pertinent interest to a given problem. The possibility of reducing both the subject content of records which are to be searched and the type of information that will be required to a relatively small number of common denominators allows the use of mechanical sorting aids. The extent of analysis of the subject matter and the type of device that can be employed for searching will be determined by such factors as the complexity of the subject matter, the number of records in the file, the type of information requested, and the frequency of use and speed requirements.

—E. E. SMITH



Springfield. An engineering career forum, individual counselling by section members, and an award program for high school students interested in engineering as a vocation were sponsored by the Student Activities Committee of the Western Mass. Section in Springfield, Mass.

A panel of five engineers including Institute members and having representatives from architectural, electrical, civil, and mechanical fields presented a five-minute resume of their respective occupations, job duties and requirements to potential engineering students from Springfield's three high schools. Fifty-five members of the Section volunteered to act as individual counsellors for students wishing advice concerning engineering and the requirements and merits of the counsellors undergraduate and graduate universities. An award consisting of a copy of the Handbook of Chemistry and Physics and an engraved certificate to be hung on the school wall was presented to the outstanding science student in each of the three high schools.

The Western Mass. Section elected as officers for 1955 V. H. Hulette, Chairman; R. G. Carter, Chairman-Elect; R. E. Colwell, Secretary; A. J. Jackson, Treasurer; A. W. Andrews, Two-year Director; E. E. Lindsey, Past Chairman; and F. Hammesfahr, One-year director.

A nuclear power plant to be economical must be built at a cost of less than \$200 per kilowatt hour, an investment reduction from present day costs of 500%, according to T. Pigford, M.I.T., in his talk before 50 members of the Western Mass. Section in November. Mr. Pigford believes that while nuclear power plants will not revolutionize industry, a predicted fuel shortage by 1975 will add greatly to the necessity for nuclear power. The advantages and limitations of high pressure water, sodium and homogeneous reactors for electric power plants were discussed.

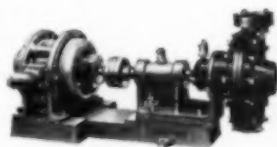
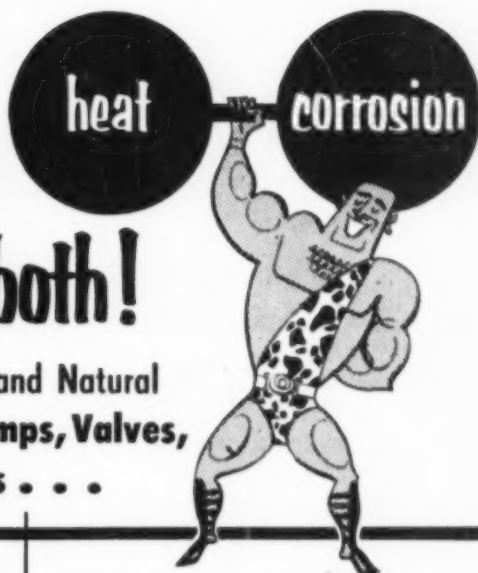
—R. T. BROGAN

Chicago. The chemical industry is divided on the use of phosphorus additives in overcoming the deficiencies of gasoline according to R. M. LaKowski of Cities Service Laboratories in his address before the November 3 meeting of the Chicago Section. The 160 members and guests present gained some insight into the current sales promotion practices of the additive field. The function, methods of evaluation, advantages and disadvantages of their use were also covered.

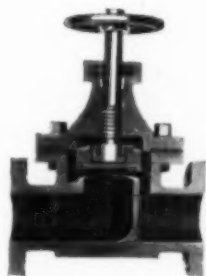
—R. BERGER

Buna N handles both!

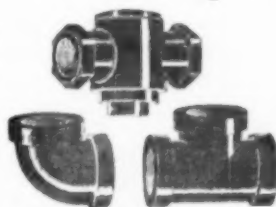
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handle a variety of tough corrosives without danger of rust or contamination. The new Buna N line resists most inorganic acids, alkalies, salts and fumes, as well as many organic chemicals . . . at temperatures up to 225°F.

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Centrifugal pumps with open or closed impellers ranging in capacity from 20-130 gpm, head to 100 feet, suction 2" and discharge 1½".

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Globe, angle and Y valves with metal reinforced stems and discs, and readily renewable seating surfaces of soft rubber. Float valves, foot valves, strainers and check valves. Sizes range to 4".

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The Cooper Alloy Foundry Co., Hillside, N. J.

Alloy: Heat Resistant 20% Chromium
10% Nickel Alloy.

Designations: A.C.I. HF, A.S.T.M.
A297-49T Grade HF; S.A.E. 70308.

Chemical Analysis: C 0.20-0.40%;
Cr 18-23%; Ni 8-12%; Si < 2%.

Applications: Used for the lower

temperature range of 1200-1600°
F. Typical uses are for oil still
supports; furnace parts; chain links;
kiln end segments; valves; grates;
etc.

Machinability: Fairly difficult. Use a
slow heavy cut and avoid work-
hardening of the surface by allow-

ing tool to glaze work.

Heat Treatment: Used in the "as-cast"
condition.

Weldability: May be readily welded
using a 0.20% C 302 rod. Heat
treatment is not necessary after
welding.

TYPICAL MECHANICAL AND PHYSICAL PROPERTIES

	Room Temperature		1200° F.	1400° F.	1600° F.
	As Cast	Aged *			
Tensile Strength, 1,000 lb./sq.in.	83	103	41	24.9	15.9
Yield Point, 1,000 lb./sq.in.	45	53.5	14	15.3	10.8
Elongation, %	38	22	30	14	16
Reduction in Area, %	32	27	42	23	39.8
Brinell Hardness	170	192			
* 24 hr. @ 1400° F. furnace cooled.					
Charpy Impact (Std. Keyhole ft.-lb.)	36				
Mod. of Elasticity (X10 ⁶ lb./sq.in.)	28				
Density (lb./cu.in.)	0.280				
Melting Point-(° F.)	2575				
Specific Heat (B.t.u./(lb.)(° F.)) @ 70° F.	0.12				
Thermal Expansion (x 10 ⁻⁶ in. (in.) (° F.)) ° F.	70-1000 70-1500 70-2000	9.9 10.3 10.9			
Thermal Conductivity (B.t.u./(hr.) (sq.ft.)(° F/ft.)) ° F.	70-212 70-1000	9.0 13.4	70-1500 70-2000	15.0 16.9	
Electrical Resistance (microhms/cu.cm.) @ 70° F.	80				
HIGH TEMPERATURE STRENGTH: (lb./sq.in.)					
	1200° F.	1400° F.	1600° F.		
Stress Rupture (100 hr.)	24,000	12,000	6,000		
Stress Rupture (1000 hr.)	17,000	8,000	3,800		
Creep (1% 10,000 hr.)	13,000	6,200	3,000		

MAX. (° F.) TEMPERATURE FOR CORROSION RESISTANCE:

Air Oxidation Resistance	1700
Oxidizing Sulfur Bearing Flue Gas (Low Sulfur)	1700
Oxidizing Sulfur Bearing Flue Gas (High Sulfur)	1700
Reducing Sulfur Bearing Flue Gas (Low Sulfur)	1800
Reducing Sulfur Bearing Flue Gas (High Sulfur)	1700

High Temperature Corrosion Resistance:

Molten Drawing and Temper-
ing Salts Fair
Molten Cyaniding Salts Fair
Molten Neutral Salts Fair
Molten High Speed Salts Fair
Molten Metal Resistance

Good resistance to mol-
ten lead. Not resistant
to molten aluminum or
magnesium.

Carburization Resistance:

Pack Carburizing Fair
Gas Carburizing (< 15% CH₄) Excellent
Carburizing in Natural Gas
(High CH₄) Poor

General High Temperature Characteristics:

This alloy has good high temperature strength and
ductility in the usable temperature range. It has fair
resistance to thermal fatigue and the effect of cyclic
heating, and its hot impact resistance is fairly good.

No. 40



News of the Field
FROM LOCAL SECTIONS

Boston. (Ichthyologists). Law Enforcement in Massachusetts was the subject of a talk given before the Ichthyologists (Boston Section) on October 22, by H. Reynolds, assistant attorney general of Massachusetts. The meeting was held at the M.I.T. Faculty Club, Boston. Of particular interest to engineers was an explanation of the administrative tribunals, i.e., medical, dental, and other professional boards of registration, and their jurisdiction over misconduct and unethical practices on the part of registered professionals. Decisions by these bodies can be and sometimes are arbitrary and capricious with very little recourse available to the plaintiff. Delegation of these powers of prosecution to the administrative tribunals is a result of overloading in the courts, and the only practical means of correcting any unfairness which may exist in the workings of the tribunals is an expansion of court facilities that they may handle all such cases.

Mr. Reynolds also criticized the professions, particularly medical and legal, for a tendency to accept practices which border on the unethical, namely, fee splitting, kick-backs, and evasion of income taxes. Frequent exposure of such cases during the past few years is planting a seed of distrust in the minds of the public toward those who have been the traditional example for moral integrity. He cited that in the case of the medical profession this may become a factor in the trend toward socialized medicine.

—A. G. SMITH

Atlanta. Methods of agglomerating dust can probably be used to control weather in the not-too-distant future according to J. DallaValle, Georgia Institute of Technology, at the October meeting of the Atlanta Section. Professor DallaValle discussed the present and future of air pollution and its solution. He pointed out that with the possibility of the occurrence in the future of radioactive dust it is advisable that more work be done to study methods for dust agglomeration and control.

—H. H. SINEATH

Maryland. Engineering for chemical plants was the subject of a talk given to the Maryland Section on October 19 at the Engineers' Club in Baltimore. The speaker, R. R. Genereaux of Du Pont in Wilmington, dealt with the way in which Du Pont controls quality and cost both in the erection of new and in the operation of existing facilities.

—A. T. OSSERMANN

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PLASTIC PIPELINE TWELVE MILES LONG

A plastic pipe line twelve miles long was installed at the rate of a mile a day in Heidelberg, Miss., to carry unwanted salt water from 25 oil wells to a central disposal plant. In laying the pipe straight trenches with flat bottoms were not needed due to the flexibility of the pipe which went in without any breakage. The pipe is made from Kralastic, a tough corrosion-resistant blend of plastic and rubber produced by the Naugatuck Chemical Division, U. S. Rubber Co.

ACHESON PLANS TEXAS PIGMENT PLANT

A new dispersed pigments and carbon black plant to supply polyethylene producers with coloring and protective pigments will be constructed in Orange, Texas, by the Acheson Industries. This geographic area was chosen because it is becoming the polyethylene center of the world. Carbon black has been shown to increase the life of exposed polyethylene from one year to more than twenty years.

The screening power of carbon black confines photo-oxidation effects to the surface layer of the polyethylene minimizing the principal cause of resin degradation. The resistance to harmful ultraviolet radiation is dependent upon dispersion of carbon black and particle size. A concentration of 2% optimum from a protective standpoint have little or no effect upon the mechanical properties of the polymer.

INSTITUTE OFFICIAL WRITES BOOK

The theoretical, technical and practical aspects of solvent and plasticizer utilization is described in a new book by A. K. Doolittle who besides being Asst. Director of Research for Carbide and Carbon Chemicals Co. is a director and recently was elected vice-president of A.I.Ch.E. The book will be a valuable reference to those concerned with the uses of solvents and plasticizers in surface coatings, plastics, synthetic fibers, adhesives and inks. The theoretical discussions will aid those interested in solvent action, viscosity and the thermodynamics of polymer solutions.



IS A PLA-TANK® STACK THE ANSWER TO YOUR FUME PROBLEM?

Shown here is a light-weight, easily-erected PLA-TANK stack which handles fume exhaust at the new thorium plant of the Lindsay Chemical Co., West Chicago, Ill.

The stack has a 44" diameter, is 69' long including 90° elbow, cross run to fan chamber and riser beyond fan. There are inlets from three floors to handle exhausts from individual tank systems. Stack was prefabricated with flanges for fast installation.

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P-20



EQUIPMENT COMPANY SPONSORS CLINIC

For the second time the Autoclave Engineers, Inc., have sponsored a program for the interchange of information about equipment and materials of construction among process operating company engineering personnel. On Oct. 4-5 at their plant in Erie, Pa., they were host to men from eight states and 29 companies and schools all involved in the chemical process industries. Problems and techniques involved in the utilization of available high pressure and high temperature equipment were brought before the group. The number of chemical process industries represented indicated that this type of program is widely appreciated by these men who are confronted with the problems of the design and use of such equipment.

The program included discussions led by two prominent men in the equipment and materials fields. J. F. Meyers, Sales Manager, Safety Head-Vent Valve Division of Black, Sivalls, and Bryson, discussed "Designing for Failure," giving a penetrating and informative talk on rupture discs. An enlightening talk and open forum on high temperature alloys was held under the direction of C. T. Evans, Manager of High Temperature Metals, Universal-Cyclops Steel Corp. Slide film illustrations charting the properties of metals used in the manufacture of high pressure vessels and equipment, offered the basis for an extensive discussion.

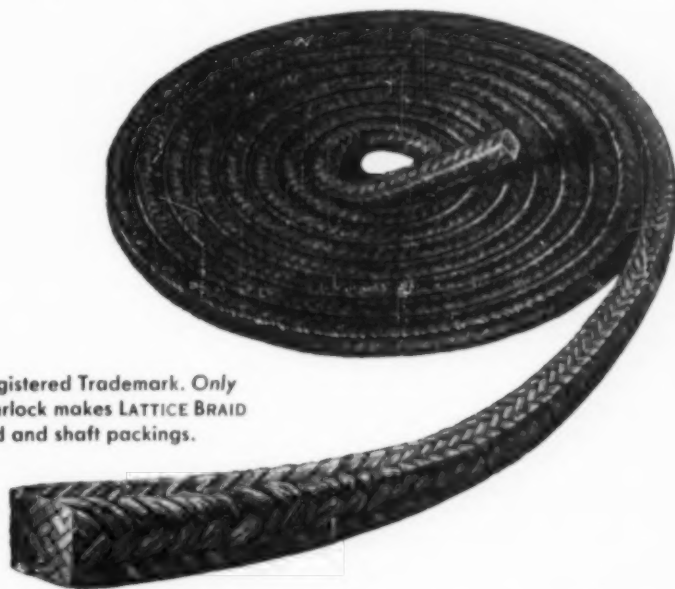
Many questions posed by guests, on manufacture, assembly, and operation of high pressure equipment, were answered by F. Gasche, president of Autoclave Engineers, and his staff. Discussion periods on the preparation of high pressure tubing, barricades, and agitation were held during the two day clinic.

GATX GRANTS PATENT LICENSE

License to use and the authority to sub-license in Europe the Kanigen nickel plating process has been granted by the General American Transportation Corp. to the Societe Europeenne de Revetement Chimique in exchange for a half million dollars plus royalties. The Societe, known as SEUREC, is composed of ten well established French industrial firms.

Developed in the last few years, the Knaigen process is a new type of Nickel plating process that is strictly chemical and requires no electricity. Pieces of many shapes, sizes and of many basis material can be plated with virtually zero porosity. Thickness can be meticulously controlled. The process was originally developed for plating the insides of tank cars.

Sharp & Dohme reports LATTICE BRAID* [†]Teflon PACKING gives excellent service on glass-lined agitators handling organic solvents



*Registered Trademark. Only
Garlock makes LATTICE BRAID
rod and shaft packings.

The Sharp & Dohme Division of Merck and Co., West Point, Pa., found that braided packings lost their shape while in use and extruded from the bottom of the stuffing boxes on their glass-lined agitators. Furthermore, some of these packings would react with the solvents in the vessels. According to E. P. Street, chemical engineer at Sharp & Dohme, LATTICE BRAID Teflon packing is not affected by the solvents, retains its square shape, and does not extrude. This has meant fewer repacking jobs and, thus, substantial labor savings to Sharp & Dohme.

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FUTURE MEETINGS and Symposia of the Institute

MEETINGS

■ ANNUAL—NEW YORK, N. Y.

Dec. 12-15, 1954. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: G. T. Skaperdas, Assoc. Dir., Chem. Eng. Dept., M. W. Kellogg Co., 225 Broadway, N. Y. 7, N. Y.

ASST. CHAIRMAN: N. Morash, Titanium Div., National Lead Co., P. O. Box 58, South Amboy, N. J.

Gas Absorption Reaction Kinetics
Biochemical Engineering Solvent Extraction

New Processes Utilizing Moving Beds

Business Organization for the
Chemical Industry
Deadline Past

■ LOUISVILLE, KY.

March 20-23, 1955. Kentucky Hotel.

TECHNICAL PROGRAM CHAIRMAN: R. M. Reed, Tech. Dir., Gas Proc. Div., The Girdler Corp., Louisville 1, Ky.

Heat Transfer

CHAIRMAN: R. L. Pigford, Div. of Chem. Eng., Univ. of Delaware, Newark, Del.

Propellant Power

CHAIRMAN: R. A. Cooley, Explosives Div., Olin Mathieson Chemical Corp., East Alton, Illinois.

Industrial Relations

CHAIRMAN: Samuel L. H. Burk, Dir. Personnel Administration, General Foods Corp., White Plains, N. Y.

Centrifugation

CHAIRMAN: J. O. Maloney, Chairman, Dept. Chem. Eng., Univ. of Kansas, Lawrence, Kan.

Solvent Extraction

CHAIRMAN: Dr. R. B. Beckman, Dept. Chem. Eng., Carnegie Inst. of Tech., Schenley Park, Pittsburgh 13, Pa.

Deadline—November 20, 1954

■ HOUSTON, TEXAS

May 1-4, 1955. Shamrock Hotel.

TECHNICAL PROGRAM CHAIRMAN: J. L. Franklin, Res. Assoc., Humble Oil & Refining Co., P. O. Box 1111, Baytown, Texas.

Nucleation Processes

CHAIRMAN: D. W. Oakley, Plant Mgr., Metal & Thermit Corp., 1 Union St., Carteret, N. J.

Flow of Fluids Through Porous Media

CHAIRMAN: H. Dayton Wilde, Mgr. Res. Div., Humble Oil & Ref. Co., Box 2180, Houston 1, Tex.

Extractive and Azeotropic Distillation

CHAIRMAN: Dr. D. E. Holcomb, Dean of Eng., Texas Technological College, Lubbock, Tex.

Chemical Engineering Curricula

CHAIRMAN: Dr. J. W. Mason, Dean of Eng., Georgia Inst. of Tech., Atlanta, Ga.

Differences in Chemical Engineering Theory

CHAIRMAN: Dr. F. A. Lendee, Dow Chemical Co., Midland, Michigan.

Deadline—January 1, 1955

SYMPOSIA

MEETINGS

■ LAKE PLACID, N. Y.

Sept. 25-28, 1955. Lake Placid Club.

TECHNICAL PROGRAM CHAIRMAN: L. J. Coulthurst, Chief Proc. Designer, Foster Wheeler Corp., 165 Broadway, New York 6, N. Y.

Process Engineering Organizations

CHAIRMAN: J. F. Thornton, Pres., The Lummus Co., 385 Madison Ave., New York 17, N. Y.

Growth of the Oil & Chemical Industry by Integration

CHAIRMAN: Mr. J. J. Simpson, Petroleum Chemicals Inc., 54 Wall St., New York 5, N. Y.

Deadline—May 25, 1955

■ ANNUAL—DETROIT, MICH.

Nov. 27-30, 1955. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. J. Carron, Supervisor, Chem. Eng. Section, Ethyl Corp., Res. Labs., 1600 West Eight Mile Road, Detroit 20, Mich.

Photochemical Processes

CHAIRMAN: Prof. J. J. Martin, Dept. Chem. Eng., Univ. of Michigan, Ann Arbor, Mich.

Biochemical Engineering

CHAIRMAN: Dr. H. O. Halvorsen, Dept. of Bacteriology, Univ. of Illinois, 362 Noyes Lab of Chem., Urbana, Illinois.

Technical Societies Cooperation with Chemical Engineering Industries

CHAIRMAN: Prof. J. B. Phillips, Dept. Chem. Eng., Phys. Sciences Centre, McGill Univ., Montreal 2, Canada.

Deadline—July 27, 1955

■ LOS ANGELES, CALIF.

Feb. 26-29, 1956. Statler Hotel.

TECHNICAL PROGRAM CHAIRMAN: T. Weaver, Proc. Eng., The Fluor Corp., Ltd., Box 7030, East L. A. Station, Los Angeles 22, Calif.

Deadline—Oct. 26, 1955

■ ANNUAL—BOSTON, MASS.

Dec. 9-12, 1956. Hotel Statler.

TECHNICAL PROGRAM CHAIRMAN: W. C. Rousseau, Proc. & Sales Eng., Badger Mfg. Co., 230 Bent St., Cambridge 41, Mass.

Deadline—August 9, 1956

UNSCHEDULED

Extraction of Hydrocarbons for Chemical Use from Pipeline Gases

CHAIRMAN: E. E. Frye, J. F. Pritchard & Co., 210 W. 10th, Kansas City 5, Mo.

Bubble Mechanics

CHAIRMAN: Prof. R. C. Kintner, Dept. Chem. Eng., Ill. Inst. of Tech., 3300 Federal St., Chicago 16, Ill.

Fundamental Mechanisms in Boiling Cavitation and Condensation

CHAIRMAN: R. R. Hughes, Shell Development Co., Emeryville, Calif.

AUTHOR INFORMATION

Submitting Papers

Members and nonmembers of the A.I.Ch.E. who wish to present papers at scheduled meetings of the Institute should follow the following procedure.

First, write to the Secretary of the A.I.Ch.E. Mr. S. L. Tyler, American Institute of Chemical Engineers, 25 West 45th Street, New York, requesting three copies of the form "Proposal to Present a Paper Before the American Institute of Chemical Engineers." Complete these forms and send one copy to the Technical Program Chairman of the meeting for which the paper is intended, one copy to the Assistant Chairman of the A.I.Ch.E., Program Committee, address at the top of this page, and one copy to the Editor of Chemical Engineering Progress, Mr. J. B. Mellecker, 25 West 45th Street, New York.

If you wish to present the paper at a particular symposium, request 4 copies of the proposal sending a copy to the Chairman of the symposium.

Before Writing the Paper

Before beginning to write your paper you should obtain from the meeting Chairman, or from the office of the Secretary of the A.I.Ch.E., at 25 West 45th Street, New York, a copy of the A.I.Ch.E. Guide covers the essentials required for submission of papers to the A.I.Ch.E. or its magazines.

Copies of Manuscript

Five copies of each manuscript must be prepared. For meetings, one should be sent to the Chairman of the symposium, and one to the Technical Program Chairman of the meeting at which the symposium is scheduled. If no symposium is involved, the two copies should be sent to the Technical Program Chairman. The other copies should be sent to the Editor's office. All manuscripts submitted to the A.I.Ch.E. Editor are automatically considered for C.E.P., the A.I.Ch.E. Journal, and the Symposium Series. Presentation at a meeting is no guarantee that manuscripts will be accepted.

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165 Broadway, New York 6, N. Y.

TAU BETA PI CONSIDERS LADY MEMBERS

A second try at opening up the membership of the Tau Beta Pi National Engineering Honor Society to lady engineers was made with majority approval at the national convention held in October at Iowa State College. The action, however, is subject to ratification by the undergraduate members of the Association who defeated a similar proposal last year with student balloting. If this year's action is again nullified by ratification vote, the chapters will still be empowered to award special badges to ladies who meet the same scholarship and character requirements required of men members.

DIAMOND ALKALI COORDINATES STAFF

Closer coordination and more effective integration of engineering activities for fifteen Diamond Alkali Plants, together with the release of additional space needed at the Technical Center in Painesville, Ohio, were two prime reasons for the recent move of the central engineering department to Cleveland.

The new office space will be located in the Union Commerce Building in Cleveland. The group will include specialists, in such fields as air and stream pollution control, corrosion protection, process instrumentation, process design, electrical system design, and structural and mechanical equipment and piping design.

INTERNATIONAL MINERALS OPENS QUALITY LAB

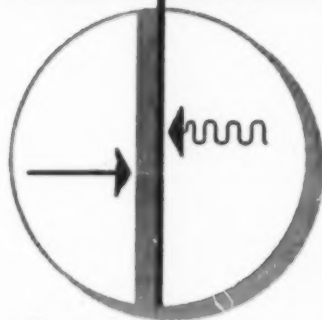
A new quality control laboratory for the analysis of nitrogen, phosphoric acid and potash in various grades has been opened in East Point, Ga., by International Minerals and Chemicals Corp. With a capacity of over 100,000 determinations per year, the new lab will keep watch on the production of International's 26-plant nutrient plants located across the country.

CHEMSTRAND PRODUCES H₂ AT NYLON SOURCE

Hydrogen is being produced at Chemstrand's Pensacola, Fla., plant for use in the preparation of chemical intermediates used in nylon production. The hydrogen is produced by reacting natural gas with steam at elevated temperatures in the presence of a nickel catalyst. Purification of the gas is accomplished by removal of the carbon dioxide by the Girbotol process. The unit was designed and supplied by the Girdler Co., Louisville, Ky.

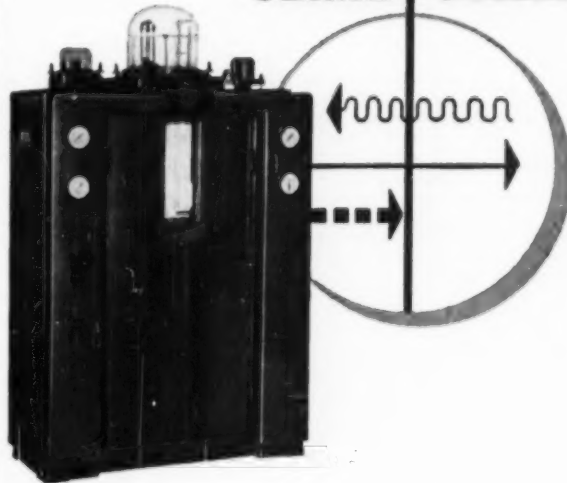
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ATOMIZATION and SPRAY DRYING By W. R. Marshall, Jr.

The theory and principles of drying are presented together with the latest developments of interest to all phases of the chemical industry—food processing, pharmaceuticals, chemicals, etc. Dr. Marshall, associate dean of the College of Engineering at the University of Wisconsin, has expanded his 1952 Institute Lecture to cover present industrial applications. (Monograph Series No. 2, 122 pages, 168 illustrations; \$3.25 to members, \$4.25 to nonmembers.)

& symposium

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**NEW AMMONIUM
NITRATE PLANT**

A 330-ton/day ammonium nitrate plant constructed at a cost of \$15,000,000 has been put in operation at Lawrence, Kansas, by the Cooperative Farm Chemicals Association. In the new plant constructed by the Girdler Co. ammonia will be converted to ammonium nitrate prills and nitrogen solutions.

The ammonium nitrate is made by reacting nitric acid with ammonia. This is accomplished in a neutralizer and results in a water solution of ammonium nitrate. C.F.C.A. uses a small portion of this solution, with added ammonia, to produce nitrogen fertilizer solutions. Most of the ammonium nitrate solution is evaporated and dried by the prilling process to make a granular solid product. In prilling the water solution is reduced to about 4% by vacuum evaporation. The resulting hot melt is sprayed into the top of the prilling tower, through which it descends into an upflowing current of air. The cooling action of the air causes droplets to solidify in the form of prills. The nitric acid necessary in the ammonium nitrate process is produced by oxidation of ammonia to nitric oxide with subsequent aqueous absorption to 60% HNO_3 .

**EXPLOSION-PROOF
CONTROL INTRODUCED**

Hazardous chemical areas having a necessity of electronic control can benefit by a new system of explosion proof conduits introduced by the Crouse-Hinds Co., Syracuse, New York. Consisting of a light source, transmitter and a photoelectric tube receiver, the system automatically activates or turns off lights, starts or stops motors, totals assembly line output or controls a number of other electrical or electronic devices.

Whenever the appearance or absence of light is detected through a lens by the receiver's photoelectric tube, a relay opens or closes the electrical circuit. The light source transmitter features a threaded adjustable focusing ring with a converging lens and an explosion-proof window. A transformer attached to the housing provides for a 115-volt primary and 5.2 secondary. The secondary voltage contributes to approximately 2500 hours lamp life.

**APPLIED MECHANICS
CONGRESS IN 1958**

The Third Congress of Applied Mechanics is scheduled to be held in June, 1958, at Brown University. Thomas B. Drew is the A.I.Ch.E. representative to the Congress. Hugh L. Dryden, director of the National Advisory Committee for Aeronautics, will head the meeting.

PETROCHEMICAL DEMAND SWEEPING UPWARD

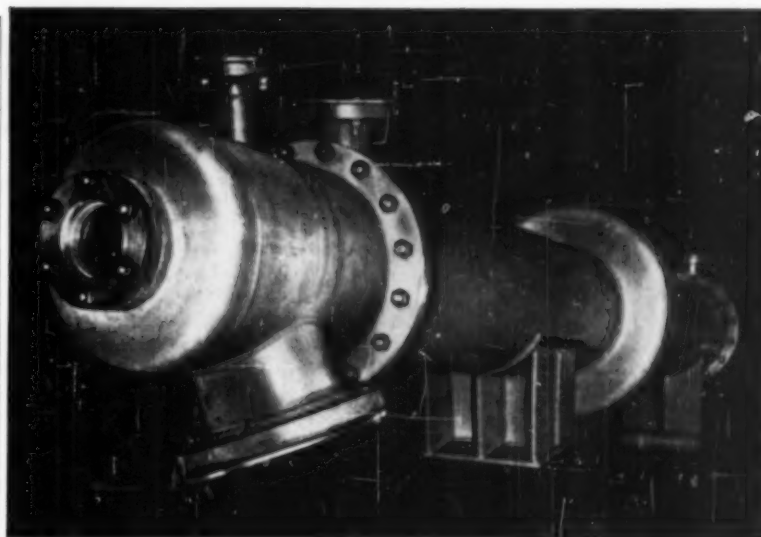
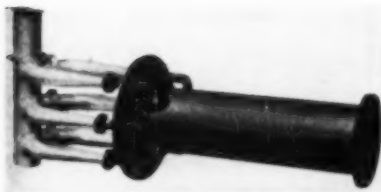
The sales value of petrochemicals which now occupy only 3% of oil refinery products will climb to 15% by 1970, according to J. B. Hill, director of research and development of Sun Oil Co. in a talk before the Sixth Annual Conference on Planning and Economics held in October in Philadelphia. Dr. Hill predicted an increase in domestic petroleum by at least 25% in this time. New developments in the science of asphalt for road building will triple its demand upon petroleum refineries in the next fifteen years. A decrease in the output of residual fuel oil will be forced by demand for lighter oil products. Among recent benefits to the petroleum industry mentioned by Dr. Hill is the new "Oxycat" process of E. J. Houdry. "Oxycat" burns up obnoxious fumes and at the same time produces useful heat from their combustion.

NEW EMPLOYEES COST \$300 TO \$1,000

The cost of hiring an employee is about \$300 an applicant according to Industrial Psychology, Inc., which bases the cost on the expense of recruiting, interviewing, testing, placing, orientation, training, and supervising of the new employee until he reaches the desired production level. For key personnel the cost is estimated at \$1,000 or more. Careful attention to hiring and placing, the research firm reasons, therefore would protect a very substantial investment on the part of most industrial corporations.

CAT CRACKER FABRICATED BY WELDING

The facility with which unusual design features may be incorporated at low cost in the manufacture of pressure vessels can be seen in a catalytic cracking unit fabricated by welding by Acme Welding, a division of the United Tool & Die Company, West Hartford, Conn. This complex unit built to function as part of a large catalytic cracking plant for refining natural gas is all welded from type 310 stainless steel.



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5"	22	20	16	19	18	12	8	4	4
6"	37	30	28	31	24	20	14	14	12
8"	68	66	60	55	48	40	31	26	24
10"	110	106	96	85	76	72	42	40	36
12"	170	156	148	126	118	104	64	64	60
14"	212	196	188	151	148	140	85	82	72
16"	283	270	252	206	196	180	110	106	100

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Seven hundred forty-eight million cu. ft./day of natural gas to completely supply the demands of Minneapolis, St. Paul, and Omaha is being distributed with the aid of the first centrifugal compressor to be used in a natural gas transmission line. Worthington Corporation's new pipeline centrifugal compressor will be used by the Northern Natural Gas Co. in a four-unit station.

Driven by a 5700 hp. two-shaft gas turbine, the pump is designed for a suction pressure of 434 lb./sq. in. with a discharge pressure of about 500 lb./sq. in. The main casing and support design have been conceived to minimize shaft center line distortions arising from high pressure in the casing. Allowing for a maximum working pressure of 1,000 lb./sq. in. the casing is designed so that various impellers may be used as the flow conditions of the pipeline may require on future expansions. The impeller is a lightweight alloy precision casting of forging providing a light totor of superior strength.

CHLORINE PLANT DOUBLES CAPACITY

Increased demands for chlorine in its own plants has caused General Aniline and Film Corp. to double the intended capacity of its chlorine-caustic plant to be installed at Linden, N. J. About \$5,000,000 will be spent for construction of the unit, which will have a capacity of 50 tons of chlorine/day. Operation of the unit, being constructed by Blaw-Knox Co., is scheduled for the fall of 1955.

1955 CONFERENCE ON NUCLEAR ENGINEERING

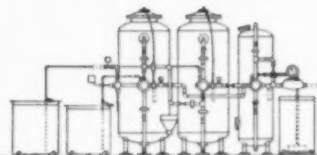
A Conference on Nuclear Engineering will be held at the University of California, Los Angeles, from April 27 through 29, 1955. One-day sessions will be devoted to nuclear reactor power extraction systems and auxiliaries, nuclear system dynamics, and radiation sources for industrial applications. Information may be obtained from T. J. Connolly, Dept. of Engineering, University of California, Los Angeles 24, Calif.

MICHIGAN U. GETS NUCLEAR REACTOR

A swimming-pool type of nuclear reactor has been approved for the Michigan Memorial-Phoenix Project of the University of Michigan by the Atomic Energy Commission. The project has been privately endowed for studies of peacetime implications and applications of atomic energy.

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nuclear engineering division

Election of new officers, preparation for the Annual Meeting, and negotiations with the American Nuclear Society for a joint nuclear congress for 1955, are among the highlights of recent activity of the Division.

Election results show the following slate of officers for 1955: *Chairman*, R. P. Genereaux, DuPont, Wilmington. *Vice-Chairman and Program Committee chairman*, W. K. Woods, G. E. Hanford Works. *Secretary-treasurer*, J. J. Martin, Dept. of Chem. Engr., Univ. of Michigan. *Executive Committee: Three year term*, W. K. Davis, Reactor Development Div., A.E.C., Washington; *two-year term*, J. R. Huffman, Phillips Petroleum A. E. Div., Idaho Falls, Idaho. Clark Center, Carbide & Carbon, Oak Ridge, was elected previously to the committee for a two year term and will serve in 1955. Donald L. Katz, retiring chairman, becomes a member of the committee for one year according to the by-laws.

Efforts to arrange a second nuclear engineering congress for the summer of 1955 are continuing. Representatives of the Division, acting through the E.J.C. Committee on Nuclear Engineering and Science, have been in communication with the American Nuclear Society offering cooperation in arranging a joint congress. So far, it is understood that the A.N.S. has tentatively indicated an interest in such a meeting provided it be held in the fall. Negotiations are continuing, with the summer being preferred by the Division because of there being fewer meetings competing for attendance and taking up available facilities during the summer months.

The annual meeting of the Division will be held December 13th, at 4:00 p.m. in Parlor B of Hotel Statler in New York. This is being held in conjunction with the Annual Meeting of the Institute. Members of the Division are urged to attend, as a number of important subjects are to be discussed. Among these will be problems of future meetings, publication, and the issuance of a membership directory.

The financial position of the Division is in such a strong state, that no increase in dues is anticipated.

JOSEPH J. MARTIN
Secretary

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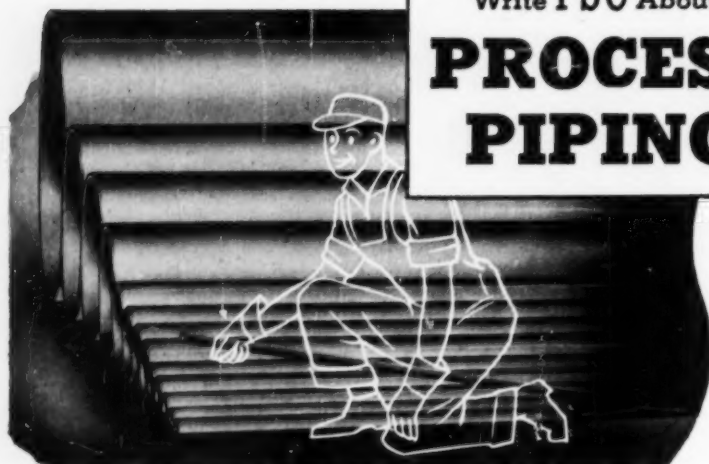
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PEOPLE

James H. Wiegand was recently named chairman of Southwest Research



Center's chemistry and chemical engineering department, San Antonio, Tex. Dr. Wiegand has been assistant chairman for the past year and was associate head of the rocket department of the U. S. Naval Ordnance Test Station

in charge of propellant development before joining Southwest Research Center. He was with the U. S. Naval Ordnance Test Station for seven years and before that was head of the Closed Chamber section of the Ballistics Research Laboratories, and a chemical engineer with the Du Pont Co.

Roger Williams, vice president, member of the board of directors and of the executive committee of E. I. du Pont de Nemours & Co., Wilmington, Del., will receive the highest award in American industrial chemistry, the Perkin Medal of the American Section of the Society of Chemical Industry for 1955. This year's award marks the forty-ninth impression of the Perkin Medal, bestowed for outstanding achievement in applied chemistry.

K. H. Rowland has been appointed Assistant Works Manager of Carbide and Carbon Chemicals Company, a Division of Union Carbide and Carbon Corporation.



Mr. Rowland joined Carbide's South Charleston, W. Va., plant as a chemical engineer in 1934 after his graduation from the University of Michigan where he earned his degree in chemical engineering. During his career at Carbide he has been Production Area Supervisor, Chemical Production Supervisor and then in 1947, was transferred to the W. Va. plant where he took over as Assistant Superintendent. In 1952, Mr. Rowland returned to South Charleston as Superintendent of Chemicals and Resins, and in 1953 was made General Superintendent of that plant.

In his new capacity Mr. Rowland will make his headquarters in New York.

Roland D. Glenn will take over as General Superintendent succeeding Mr. Rowland.

FROLICH TO HIGH POSITION IN CHEMICAL CORPS

Per K. Frolich, vice-president for scientific activities at Merck and Company, joined the staff of Major General Wm. M. Creasy, chief chemical officer of the Department of Defense. Dr. Frolich will serve both as deputy for scientific activities and as the Corp's chief scientist.

In an address given before the New York Section annual meeting of the Armed Forces Chemical Association, General Creasy termed Dr. Frolich "highly respected in the industrial and scientific world, and [who] will most assuredly greatly strengthen the leadership in the Corps research and development field."

CORRECTIONS

Errors were committed in the text of articles appearing in the November issue. On page 76 in the article titled "Synthetic Ammonia" it states that 18 new plants and expansions were put on-stream in the period of Jan. to Sept. of this year. This statement should read "in the period of Jan. 1950 to Sept. 1 of this year." Further on it states that "over 70% of these will go into this area which already accounts for 70% of the country's synthetic ammonia output." This should read "over 70% of these will go into this area which already accounts for 87% of the country's synthetic ammonia output." It also states that "there is a noticeable lack of production in the heavy fertilizer consuming areas in the southwest." This should read "southeast."

In that same article Mr. C. H. Davenport's affiliation was omitted. Mr. Davenport is the Manager of Engineering & Process Development, Research Division, Lion Oil Co.

In the New York one-day meeting report, on page 60, in the article "New Developments in Textile Fibers" Mr. Fremon's name was erroneously spelled.

In the October, 1954 issue of C.E.P., item 228 of "A chemical engineer goes to the instrument show" was incorrectly identified as a Leeds & Northrup pH indicator. Instead, this was a Schutte and Koerting pneumatic transmitting rotameter for direct indication of rate of flow of fluids. It can be used with a standard pneumatic receiver with 3 to 15 lb./sq.in. air supply. Will remotely record, control and integrate rate of flow.

Further information may be obtained by writing Mr. F. L. Siebold, vice president, Schutte & Koerting Company, Cornwells Heights, Pa.

the chemical engineer in sales

More firms each year are filling purchasing agent jobs with men having engineering training, according to Stuart F. Heinritz, editor of *Purchasing*, in addressing the Chemical Equipment Sales Engineers Association. The November meeting took place in the Chemists' Club in New York.

There is a distinct trend, according to Mr. Heinritz, on the part of purchasing departments of the major manufacturing firms to intensify their making of analyses of comparative specifications of available products to determine the effect of variables on the manufacturing operation.

Such studies do not attempt to evaluate directly the effect of product variables (specifications and cost) on processing technology or economics. Such information is solicited from the engineering and treasury departments.

The principal source of information on product variables for such studies is the sales engineer, according to Mr. Heinritz. To be most useful in this role, the sales engineer should make his own analysis of the interests and information needs of the purchasing department, and then endeavor to present his data in a most useful form.

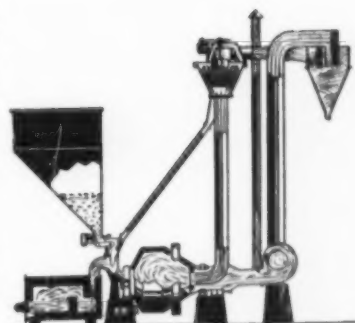
It is advisable for one to be alert in determining which products are of greatest interest. Most plants place the bulk of their dollar-volume of orders in relatively few items, which conversely means that these few items are likely to have the largest effect on at least the economic balance sheet, if savings can be made.

In the chemical process industries, however, exceptions to this rule are often the case. An example might be a catalyst bought at a relatively small expenditure, but which might bring about major technologic or economic advantages through its improvement.

The over-all purpose of these analyses is to permit the setting up of intelligent allowable limits in purchasing specifications which do not block suppliers, but instead enable screening of products to assure consideration of the best.

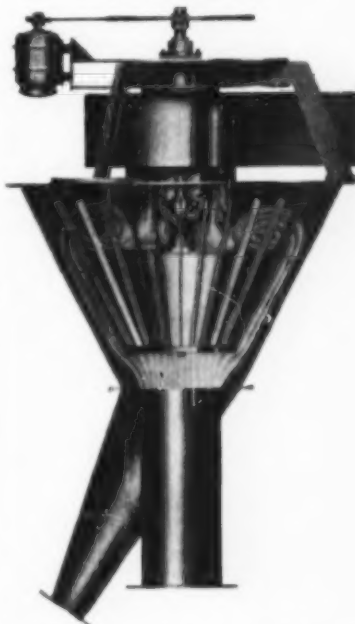
Wholehearted assistance in the development of such analyses will pay off, according to Mr. Heinritz, in many ways. Among those mentioned were greater cooperation on the part of purchasing men in helping the sales engineer reach the most appropriate engineering specialists.

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HARDINGE "GYROTOR" PROVIDES CLOSE CONTROL OF PRODUCT



Hardinge Company, Incorporated, York, Pennsylvania, recently announced a completely new type of dry classifier—the "Gyrotor" Air Classifier, designed for extremely close control of product in a dry grinding or separating operation. It can be used in closed circuit with a pulverizing mill or as a self-contained sizing unit for any moving stream of air solids mixture.

The classifier has a wide range of fineness control, and adjustment of product size is made simply by changing the rotor speed. Hardinge Bulletin AH-449-40 describes this new classifier in detail.

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Ernest H. Volwiler, president of Abbott Laboratories, North Chicago, Ill., and chairman of the board of directors of the American Chemical Society, is the recipient of the Chemical Industry Medal of the American Section of the Society of Chemical Industry. He was honored for his contributions to the development and manufacture of organic chemical products valuable in medicine. The medal has been awarded annually since 1933 "for conspicuous services to applied chemistry."

J. G. Detwiler has been appointed to the staff of Foster D. Snell, Inc. of New York as a Petroleum Consultant. Mr. Detwiler will be available for consulting work on the chemical problems of the petroleum industry.

Richard D. Hedreen succeeds Harold A. Lewis as manager of the Explosives Department of the DuPont Company in Chicago.

Dr. W. A. LaLande, Jr., vice president, Research and Development of the Pennsylvania Salt Manufacturing Company, has been named associate trustee of the University of Pennsylvania.

Jean R. Okel will assume management of project evaluation for the development department of Monsanto Chemical Company's Research and Engineering Division this month.

Ed Demarest of Blaw-Knox Company has been transferred from California to be New York District Manager. **James C. Casten** has joined the California office of the company from Buffalo.

R. McFarlan, technical director of Hills-McCanna Company, has been elected Secretary and **W. H. Mashinter** has been appointed Director of Research and Development.

Mobay Chemical Company announces the appointment of **Donald J. Miller** as plant manager of the new Mobay plant near New Martinsville, W. Va. **Peter J. Baker** has joined the Mobay branch at Anniston, Ala., in the Application Research Section.

Diamond Alkali Company recently appointed **Gene W. Noce** to the position of Production Supervisor, and **Richard J. Blaha** as Area Supervisor at the Muscle Shoals, Ala., plant.

The J. F. Pritchard Company of Kansas City recently appointed **H. Arthur Martin** as executive vice-president and **W. W. Deschner** as a new vice-president.

Charles J. Schleeweis has recently been appointed Sales Manager of the Johnston Pump Company.

Joseph Adinoff has joined American Potash Chemical Corp. as chief engineer of its Eston Chemicals Division at Los Angeles. In this capacity he will supervise all phases of engineering in connection with the division's production of agricultural chemicals, aerosols and refrigeration chemicals. A graduate of the University of Michigan with a B.S. degree he was previously employed by Parke Davis & Co., Detroit, Mich.



Robert H. Dodd has been appointed head of chemical engineering in the Oklahoma Institute of Technology, A&M's engineering school. Dr. Dodd, who is on a two-year leave of absence from the Lummus Co., fills this post left vacant by the death of Dr. Luis Bartlett two years ago. During the interim, **C. L. Nickolls**, also a member of the A.I.Ch.E., has been acting head of this department.

Dr. Dodd organized the English subsidiary of the Lummus Co. which handled the design and erection of petroleum refineries and chemical plants in Europe. Before joining the Lummus Co., Dr. Dodd had been with the Shell Oil Co., Standard Oil Development Co., and the Gulf Oil Corp., working in the chemical engineering departments over a period of ten years.



R. H. DODD

E. W. HANSZEN



E. W. Hanszen is president of the Hanszen Plastics Co., Dallas, Tex., a new Southwestern firm which will do custom moulding, manufacture glass fiber, and handle special requirements. Mr. Hanszen has had twelve years' experience in the plastics industry and was formerly area supervisor of the Texas City plant of the Carbon and Carbide Chemicals Co. He holds a master's degree from M.I.T. He recently announced the initial steps in the construction of a plant for the manufacture of plastics and fiberglass laminates.

Ralph Resnick and **Roger N. Pauls** have joined Hooker Electrochemical Co. as technical employees at the Niagara plant.

Raymond W. Fahien was recently appointed assistant professor of chemical engineering and associate engineer in the Ames laboratory of the Atomic Energy Commission, at Iowa State College.

Gerard N. Vriens has been appointed a group leader in the intermediates and rubber chemical development section, Bound Brook plant, American Cyanamid Co.

Kaiser Engineers division of Henry J. Kaiser Co. has acquired the services of K. J. Caplan, air pollution engineer and a specialist in industrial hygiene engineering for the past twelve years.

I. E. Miller, formerly group leader in the Sugar Creek Laboratory of Standard Oil Co. (Indiana), was promoted to superintendent of the Mandan Laboratory of the company.

The appointment of Donald E. Mariner, of the Houston district, to the sales office in Wilmington, Del., was recently announced by the Monsanto Chemical Co.

E. Russell Griffith, formerly associated with the gas department of Ford, Bacon and Davis, Inc., has joined the American Gas Association as research engineer. He will be employed primarily on pipeline research work. He has been associated with the DuPont Co. in explosives manufacture and research and development at the Alabama Ordnance Works and Eastern Laboratory.

Homer Z. Martin, presently director of the development division, Standard Oil Development Co., Linden, N. J., has been transferred to the research division as assistant director for one year on a rotational assignment. Henry J. Ogorzaly, who is a member of the development division takes over as director.

Frederick J. Hill was recently appointed senior process engineer, research and development department, American Viscose Corp., Marcus Hook, Pa. Prior to joining American Viscose, he was a research section leader with the International Mineral and Chemical Corp., Chicago, Ill.

Howard Harmon of Pacific Valves, Inc. has recently been appointed the mid-continent district manager in charge of the Tulsa office.

Dr. Malcolm M. Renfrew has taken over the duties of Director of Research and Development for Spencer Kellogg and Sons, Inc., Buffalo.

DuPont Company has named Andrew E. Buchanan, Jr., to succeed Robert L. Richards as general manager of its Textile Fibers Department.

Charles M. Thatcher has joined the staff of the Whiting Research Laboratories of the Standard Oil Co. (Indiana).



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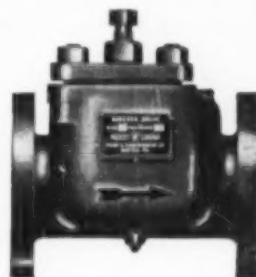
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CAPABLE, VERSATILE, MATURE CHEMICAL ENGINEER—Seven years' process design; three years' operations and trouble shooting; five years' evaluations (technical, process, economic); nine years' teaching, evenings (graduate level). Prefer position responsibility, challenge. Head up small chemical engineering department; be assistant to manager, large department; be technical assistant to demanding executive. Patents, publications, advanced degrees: Sigma Xi, Phi Lambda Upsilon, A.I.Ch.E., A.C.S. Salary required \$12,000-\$15,000 annually. Box 2-12.

CHEMICAL ENGINEER—Age 35. B.S. 1943. Supervisory development experience, four years' military explosives, seven years' wood products. Includes production trouble shooting, statistics, economic evaluations. Desire administrative, development, production or sales position in Arizona, New Mexico, or nearby area. Box 7-12.

PROJECT ENGINEER—P.E. Cost estimates and construction proposals prepared for selected processes in organics, fats, oils, detergents, and pharmaceuticals. Flow-sheets and layouts. Consulting basis only. Northeast. Box 8-12.

CHEMICAL ENGINEER—Age 32. B.Ch.E. Twelve years' experience in process design and operations with major petrochemical company. Present status supervisory capacity. Current salary \$9,000. Desire position of increased responsibility with expanding company. Box 9-12.

B.S. in Ch.E. 1950—Age 26, family. 4½ years' varied experience in production, engineering, and development. Desire position in South. Box 10-12.

B.S.Ch.E.—Age 36. Seven years' experience in chemical engineering and five years' experience in mechanical engineering. Most of experience in field of phosphate fertilizers. Desire position in process development or production. Box 11-12.

STIFLED now, seeking position with greater challenge to abilities in production, pilot-plant, or project engineering. B.S.Ch.E. Age 32, married. Ten years' experience covering production supervision, process and product development, process engineering studies. Eastern location. Box 12-12.

SENIOR CHEMICAL ENGINEER, Ph.D.—Fifteen years' administration and supervision major programs in process development and process engineering. Organics and petrochemicals. Technical director or similar senior capacity. Box 13-12.

CHEMICAL ENGINEER—B.S. 1941. Thirteen years' varied experience. Last seven in development, rubber chemicals and organic pigments. Plant, pilot-plant, laboratory background. Desire stimulating position with future in development. Age 35, married, family. East preferred. Box 14-12.

YOUNG EXECUTIVE—S.M. in Ch.E., M.I.T.; P.E. Eight years of broad experience in process development, pilot-plant supervision, project engineering. Accustomed to relieving the boss of his problems. Box 16-12.

TECHNICAL SUPERVISOR; QUALITY CONTROL—Diversified production experience, both heavy and specialty organics including production supervision, trouble shooting, product and process development, customer service, etc. Thorough knowledge of and experience in quality control and statistical analysis. Heavy supervisory experience. Box 15-12.

CHEMICAL AND SANITARY ENGINEER—Academic and industrial experience including research and development in petroleum, protein, high-pressure work, four years' teaching, three years' supervisory experience. Veteran. Box 17-12.

CHEMICAL ENGINEER—M.Ch.E. Age 29. Seven years' outstanding experience, petroleum and petrochemicals. Currently group leader, process design and development, technical service, economic analysis at major refinery. Distillation, heat transfer consulting experience. Want more demanding, responsible job anywhere. Current income \$8,700. Box 18-12.

CHEMICAL ENGINEER—B.S.Ch.E. 1949. Age 27, married. Five years' experience in production supervision and development with large chemical company. Desire position as development engineer in West or on West Coast. Present salary \$6,000. Box 19-12.

CHEMICAL ENGINEER—B.Ch.E. 1951. Age 26. Registered engineer-in-training (Michigan). Due for discharge from the Army about December 25th. Two years' experience quality control, one year's process development. Process-development or plant-engineering work preferred. Midwest area. Box 20-12.

PROCESS ENGINEER—Age 38, M.S. 1945, veteran. Fifteen years' diversified experience. Last three years process design and development petroleum and petrochemicals. Five years' teaching. Desire responsible position management or teaching. Minimum salary \$7,500. Box 21-12.

ENGINEER—B.Ch.E. 1949. Seeking affiliation with small consulting firm or equipment manufacturer (sales). Experience includes production supervision, waste-water-treatment plant design, public relations. Also teaching night classes at extension school. Age 34, married, family. Will relocate. Box 22-12.

SALES ENGINEER—With organization having wide experience and contacts wishes additional representations chemical-process equipment and allied for western New York and northwestern Pennsylvania. Box 24-12.

SALES EXECUTIVE—CHEMICAL ENGINEER—Thirteen years' engineering, sales experience. B.Ch.E. Member A.C.S., A.I.Ch.E., wide contacts. Now Eastern district manager for heat exchanger manufacturer. Seeking executive sales opportunity preferably in New York area. Box 25-12.



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PEOPLE

(Continued from page 91)

Dr. J. Perry Morgan assumes expanded duties on the Atomic Energy Commission with his appointment as deputy manager of the broadened St. Louis AEC area as well as for the new Weldon Springs, Mo., project.

Paul A. Koons has joined the sales organization in the Chemical Division of the Goodyear Tire & Rubber Company.

Norman H. Parker is manager of engineering for the Turbo-Mixer Division of General American Transportation Corp. in New York.

Robert E. Zinn, professor of chemical engineering, Northwestern University, has recently become a partner in Vern E. Alden Co., Chicago, Ill.



He plans to continue as a full-time member of the University's technological institute. Prior to joining Northwestern's faculty in 1951, he was chief engineer with the Victor Chemical Works, Chicago Heights, where he began as a junior chemical engineer in 1927.

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Necrology

Chemical Engineering Progress recently was notified of the death of the following members:

Samuel Schmucker Sadtler of Samuel P. Sadtler and Son, Inc., Research Laboratories of Philadelphia.

Mr. Sadtler, 81, was graduated in 1895 from M.I.T. with a degree in chemistry. In 1900 he joined his father as a consulting chemist. Before becoming a member of the A.I.Ch.E. in 1908 while his father was president of the organization, Mr. Sadtler had helped found the Chemists' Club in New York.

During his career he had obtained over thirty U. S. patents on such subjects as nitro cellulose, asphalt paving, and nitro starch. Mr. Sadtler wrote one book, "Chemistry of Familiar Things." Construction of the Tubize Chattillon Company in Hopewell, Va., for the manufacture of rayon was among his more important engineering projects. Publisher Industries in Philadelphia is one of the larger companies started by the Sadtler father and son team.

Harry Heller, retired vice-president of the Mutual Chemical of America in Baltimore.

Mr. Heller, 68, joined the American Sugar Refining Co. after his graduation in 1908 from the University of Pennsylvania with a degree in chemical engineering. When he came to Mutual, Mr. Heller was successively engaged in experimental work, operating, redesigning and reconstructing in connection with bichromate manufacture and construction for sulphuric acid manufacture. Also, while he was in the capacity of chemical engineer there, Mr. Heller designed and installed a new operating plant for one bath tonnage.

Irving Siller, head of the tubular heat exchanger section of The Pfaudler Co., Rochester, N. Y.

Mr. Siller, 31, was a graduate of the University of Rochester in 1943 with a B.S. in chemical engineering, and of Case Institute of Technology in 1946 with an M.S. in chemical engineering. He joined Pfaudler in 1946.

Edwin C. Warren, chemical engineer with the Union Bag and Paper Co.

Mr. Warren had joined the company after his graduation in chemical engineering from Syracuse University, 1951.

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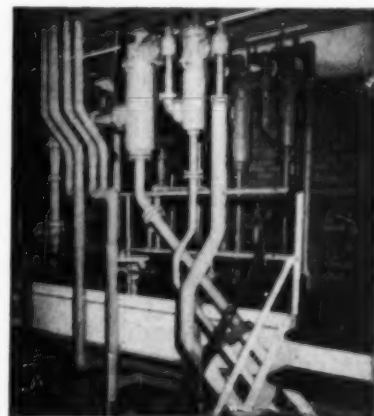
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A.I.Ch.E. News And Notes

How better to close this year than with a salute to S. L. Tyler, retiring executive secretary of the A.I.Ch.E.!

This issue should be in the mails about the same time Council & the Institute members honor "Steve," as we have come to know him, at the Annual Awards Banquet.

New York Section gave him a surprise salute. Francis B. White, former chairman of the group, talked about the growth of the A.I.Ch.E. under S.L.T.'s guidance . . . & also gave him a silver cigarette box inscribed "To Stephen L. Tyler with affectionate regard from the New York Section of the American Institute of Chemical Engineers, November 17, 1954."

Steve is a past chairman of the New York Section . . . but other sections too have a feeling of warm regard for him as witnessed by the gift from local sections . . . collected by Institute Section Committee chairman Stanley Lopata & presented at the annual banquet.

Institute growth has been steady under S.L.T.'s guidance & many local groups owe their beginning to him.

In April, 1937, the beginning of S.L.T.'s stewardship, the A.I.Ch.E. had ten local sections. Today there are forty-eight, with seventeen clubs formed & looking toward local section status.

Other statistics are just as impressive. . . . From two employees (Mrs. Sheerin, his secretary, is still with us) in 1937, we have grown to a staff of over forty. . . .

Membership then was 1,435, today it is 14,400.

Yearly income has grown from \$26,000 to almost \$500,000.

Office space originally was 500 sq. ft.; today we occupy 5,000 sq. ft.

Publications in 1937 . . . a quarterly Transactions with a total of about thirty-five articles a year. . . .

Today we have a monthly publication offering over one hundred articles annually, a Symposium Series which will print this year about one hundred & fifty articles, an active program of other publications covering problems, directories, book lists, preprints of meeting articles, all offered either free or at the

bare cost of printing and mailing.

Then too, we are about to begin a new venture, a quarterly publication, the A.I.Ch.E. Journal, which we hope develops new publishing horizons in chemical engineering research.

From a semiannual & an annual meeting a year, the A.I.Ch.E. meetings have increased to four meetings, three of them on a regional scale, which enables smaller gatherings of the clans in areas which could not accommodate the larger annual meetings. . . .

Important too in the meeting picture are the many one-day sessions of local sections. . . . They have all been part of the general encouragement & growth of the A.I.Ch.E. & chemical engineering.

Another of S.L.T.'s important contributions to the field has been his activity in sponsoring close cooperation between ourselves & other engineering groups . . . through Engineers' Council for Professional Development & Engineers Joint Council.

He was on the Advisory Committee to General Hershey, director of Selective Service, & out of S.L.T.'s vast knowledge of the selective service operation has come much of the progress of the Engineering Manpower Commission of Engineers Joint Council.

During the war he was on the Technical Information Committee of N.S.R.B. & went to London for a three-month period as Director of the T.I.C. office. He then went to Germany & France to help in the coordination with the British on technical information in the chemical field.

In his seventeen years as executive secretary of the A.I.Ch.E., Steve says, the most gratifying experience is the collective one of seeing chemical engineering as a course, as a profession, & as an honored calling coming to full fruition. He feels that this is due largely to the growth of the Institute & its activities & the growth of the chemical industry & that it has been aided by the many extracurricular activities of Institute committees.

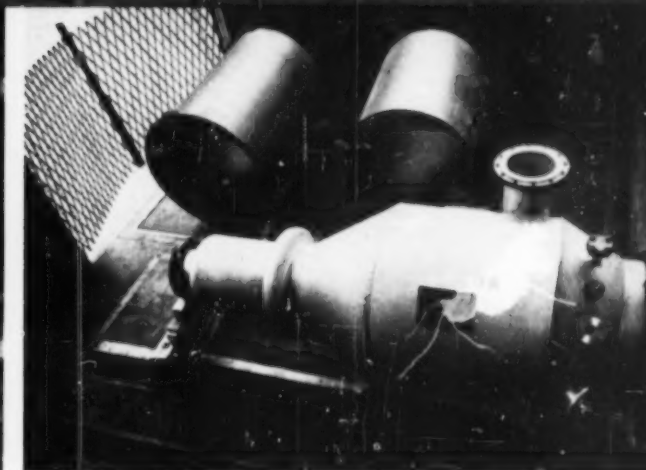
Our best wishes go with him - may his retirement be peaceful, his memories full, & his life long.

F.J.V.A.

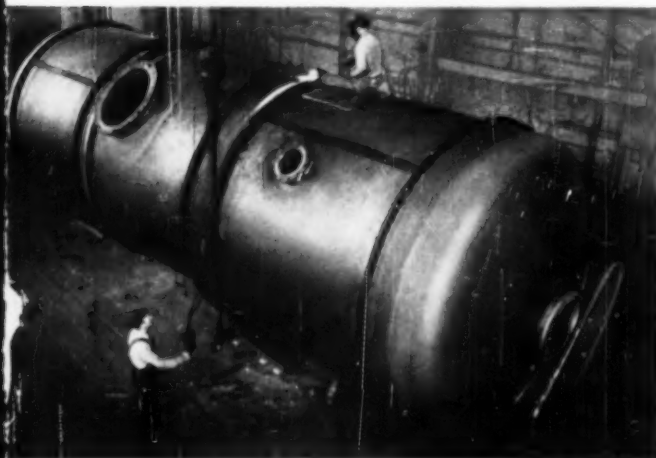
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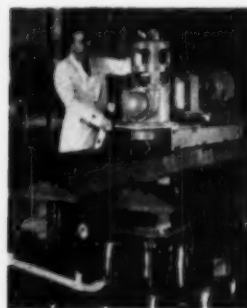
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